LAND EVALUATION STUDIES IN HUNGARY

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AKADÉMIAI KIADÓ • BUDAPEST

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IN HUNGARY

(Studies in Geography in Hungary 23)

Edited by
D. Lóczy

The Geographical Research Institute of the Hungarian Academy of Sciences has elaborated a method for determining cropspecific land suitability. The first part of this volume briefly describes this procedure and the way land suitability grid maps for individual crops are combined to show the areal distribution of types of agricultural habitat. The resulting regionalization is an important tool for regional planners since it portrays the allocation of land resources on a simple map and promotes specialization.

The agroecological regions thus identified can, however, only reflect the physical potentials in the area. For a complex land evaluation this first stage of the survey has to be supplemented with the assessment of economic factors. As the complete methodology of an economic evaluation of land has not yet been elaborated for Hungary in a final form, an experimental method is presented here by L. Góczán (who has also guided the agroecological regionalization project). In the second part, he attempts to compute another numerical value incorporating gross crop production value, labour and capital investments as well as the numerical value of the agricultural habitat.

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Edited by
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PREFACE

Agriculture is an outstanding branch of the national economy of Hungary. The demand for agricultural produce is not limited to the nutrition of home population, but also observed in respect to the balance of foreign trade, considerably dependent on the exports of farming products processed at high levels. Some crops and by-products are indispensable for industrial use and required in growing amounts.

The present economic reform in Hungary aims at introducing a new system of economic regulation, which is meant to encourage the better utilization of environmental resources. This increased reliance on natural potentials is indisputably imperative in field cultivation, where the control of environmental factors on production is the strongest and, supposing more appropriate economic regulation, the adjustment of production patterns to land capability would provide opportunities to raise profitability at relatively low levels of investment.

In order to plan the optimal use of land, up-to-date information has to be available for the farms, on the quality of their land. The new land evaluation scheme under way rates tracts of land on a relative scale with numerical values of habitat ranging from 0 to 100 based on a nation-wide soil survey. In the Geographical Research Institute of the Hungarian Academy of Sciences a method for determining crop-specific land suitability has been elaborated. The first essay of this volume briefly describes this procedure and the way land suitability grid maps for individual crops are combined to show the areal distribution of types of agricultural habitat. The resulting regionalization is an important tool for regional planners since it portrays the allocation of land resources on a simple map and promotes specialization, a desirable trend encouraged by the state.

The agroecological regions thus identified, however, only reflect the physical potentials in the area. For a complex land evaluation this first stage of the survey has to be supplemented with the assessment of economic factors. As the complete methodology of an economic evaluation of land has not yet been elaborated for Hungary in a final form, an experimental method is presented here by L. GÓCZÁN (who has also guided the agroecological regionalization project). In the second paper, he attempts to compute another numerical value incorporating gross crop production value, labour and capital investments as well as the numerical value of the agricultural habitat. A modified variety of COBB-DOUGLAS' production function was selected to do this task and solved with the help of coefficients of volume elasticity. Examples illustrate how the price of land is calculated for two farms of different ecological endowments.

Both methodological studies are meant to contribute to the nation-wide survey of Hungary's most important natural wealth, fertile land.

Budapest, April 7, 1988

Dr Dénes Lóczy

editor

PART 1

AGROECOLOGICAL REGIONALIZATION ON THE BASIS OF SUITABILITY FOR CROP CULTIVATION: EXAMPLE OF KOMÁROM COUNTY

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1. INTRODUCTION

In Hungary the century-old, outdated 'Goldkrone' land evaluation, based on cadastral net income, is now being replaced by a new system.

The new evaluation system is launched by a government act and being introduced in two phases. In the first phase the qualities of the habitat limiting possible ecological yield are evaluated which are relatively constant components of the value of habitat.

The result of this agricultural habitat evaluation is the *score value of habitat* going to replace the old land value index expressed in net income in the land registry.

The other, relatively fast changing, component of the score value of habitat is to be calculated through economic land evaluation. However, there is no established method for such evaluation yet.

Although promising experiments of elaborating *complex land evaluation* methods (BENET, I. - GÓCZÁN, L. 1973, a,b; NÉMET, L. 1970; SZÜCS, I. 1980a; FEKETE, F. 1984) taking into consideration the ecological differences in habitats (unlike the previous methods), have been made in the last two decades, they do not meet all the requirements of a modern land evaluation, since they do not include the land value component derived from the *location-dependent land rent*.

Calculating this location-dependent rent is rather difficult in Hungary. On the one hand, state purchase prices do not include transport expenses, on the other hand there is no appropriate *agroecological regionalization* in the country which could render this calculation possible.

The lack of agroecological regionalization has a disadvantage to the central planning of agriculture, viz. the elaboration of a rational land use model of the country required by a government decree.

2. CONCEPTS FOR DELIMITING AGRICULTURAL MICROREGIONS

Research workers undertook to set up an up-to-date agroecological microregionalization methodology, which is presented in this report and applied to one of the counties of Hungary.

István LÁNG, the secretary general of the Hungarian Academy of Sciences conducted a significant research project ("The agroecological potential of Hungarian agriculture by the turn of the millennium" 1979-82 - LÁNG, I. et. al. 1983) containing an agroecological regionalization of Hungary (GÓCZÁN, L. - NEMERKÉNYI, A., 1980), but it was actually the adjustment of the boundaries of the new physical geographical mesoregions (PÉCSI, M. - SOMOGYI, S. 1980) to the administrative divisions. True agroecological boundaries were only dominant in the case of very prominent ecological contrasts. Naturally, physical geographical regions cannot be identified with agroecological regions. The former represent more or less 'homogeneous' areas to the totality of physical geographical factors;

the latter are separable due to the degree of suitability for the ecological requirements of various plants.

Identifying agroecological regions cannot be restricted to only finding their boundaries, tracts of agricultural land has to be assessed from the viewpoint of its suitability for cultivation. The agroecological potential of a certain area can be revealed by deciding the most suitable plants to grow there and the degree of this suitability. In other words, the ecological suitability for crop cultivation of agricultural areas has to be decided. In doing so the chosen areal units should be applicable to agricultural co-operatives and state farms, e.g. 25 ha areal units are suitable as they answer the size of an average plot. As most information needed for the assessment can be derived from maps, the 25 ha areal units are to be constructed by overlaying a matrix (identified by x, y co-ordinates) on the maps.

In this way, however, the boundaries of agricultural farms are not observed, the total spatial agroecological data base of the country is going to be compatible to computer handling.

Such an agroecological regionalization method with proper, scientific viewpoints of suitability assessment remarkably reduces the subjectivity in defining the regions. During the suitability assessment the mosaics of the assessed 25 ha areal units are arranged into types of habitat in observation of spatial ecological regularities. Their homogeneous or heterogeneous juxtaposition brings about objectively separable regions.

The such constructed agroecological regions have more scientific and practical merit than regions constructed in any other way. Its first scientific and practical profit lies in its being an important tool to the new land evaluation.

The present cropland value score in the land register does not give any more information than expressing the relative quality of land compared with the best in the country. It does not give information about the crop to grow there and the suitability for its cultivation.

Our map of agroecological regions based on ecological suitability for crop growing, gives the above information for every 25 ha agricultural area.

In this sense, *our agroecological regionalization method can promote and complement the land evaluation under way.* Another merit is its availability practically for every farm. Its background data - for every 25 ha areal unit - are stored in computer files and can serve as a basis of a *land information system* too.

Finally, possessing suitability map *the utilization and exploitation of ecological endowments* can be monitored by digitally processed, satellite land use (crop pattern) maps. Its importance for the central planning administration can hardly be overestimated.

3. LAND EVALUATION AND AGROECOLOGICAL POTENTIAL

The problem rises from judging the productivity of arable land. The expressions "land, habitat, soil, arable soil productivity or fertility, capacity" are commonly used both in publicistic and professional literature.

The proper scientific expression in our case is the *natural fertility of agricultural habitat* and the *productivity of agricultural habitat.*

The natural fertility of agricultural land refers to the yield possible in a given area with constant physical (habitat) endowments, without applying any artificial nutrients and fertilizers and irrigation only relying on a simple agrotechnique.

By constant habitat endowments we mean relatively stable properties of the following: soil type, soil subtype, texture, humus quality and quantity, thickness of humus layer, acidity, $CaCO_3$ content, leaching, organo-mineralic complexes and their adsorptional conditions, porosity, water capacity and permeability, eluviation and illuviation exchanging matter between soil horizons, thickness of fertile soil layer; parent rock, water supply, agroclimate and relief.

3.1. Agricultural habitats

In its original state, such an agricultural habitat is a natural ecotope. In our cultivated lands the agrotechnique, the organic residue of economic crops grown in rotation, not observing the boundaries of ecotopes and the enduring microclimates of habitats, obscured the natural ecotope boundaries, and created *agricultural habitats with similar - but no more identical - ecological endowments.*

An excellent example for this in Hungary is the once homogeneous ecotope covered by chernozem, formed on a westwardly exposed valley slope on loess parent rock. Half of it has kept its original thickness of humus layer due to contour observing mass cultivation, while the neighbouring small-plot slope cultivation area - which used to be the same ecotope - has become a completely eroded loess surface. Ramann's brown forest soil has been eroded down to the loess parent rock on the eastwardly exposed slope of the same valley. The present agricultural habitats include the divergences of once identical ecotopes and the convergences of once different ecotopes.

3.2. Agroecological potential of an agricultural habitat

It means the actual fertility of cultivated land having been affected by some agrotechnique. This potential depends on the way the habitat responds to ecotechnical, agrotechnical and agrochemical effects and the degree of possible economic effectiveness of these effects on a given, modern technical level of production. This productivity can be called *agroecological potential.*

Every country and national economy is basically interested in preserving the agroecological potential of the cultivated land.

Central planning authorities are also interested in subdividing agricultural land with similar agroecological potentials, so as to be able to incite economy to obtain more profit and land rent obsessing the best ecological endowments through *specialization*.

Agroeconomics is concerned with differences in land quality when stating the differential rent or the differential net income. Actually it means the geographical differences in the agroecological potential of cultivated land.

To measure these differences, first the quality criteria of the best habitat properties in the country have to be established so that the score value of habitat can be compared with it.

The simplest and most reliable way of accomplishing it is to compare the endowments of the cultivated land with the average crop yields. The average of the inter-war period should be selected for reference, as chemical fertilizers did not affect the quality of arable land then.

This comparison offers a *rating possibility* which assigns maximum ranks to the best habitats (with the highest crop yields at a given agrotechnical level) and minimum ranks to the worst, infertile lands.

All the different quality habitats can be rated proportional to their value between the best and worst (highest and lowest scores on the score range) cultivated lands.

3.3. Land evaluation concepts

This concept has been realized in several countries (TEACI, D. - BURT, M., 1974) and in Hungary too, with an agricultural land evaluation using scores from 0 to 100. Its implementation was made compulsory by a resolution related to the Land Act as mentioned above (In: Mezögazdasági és Élelmezésügyi Értesitö, August 22, 1982).

This land evaluation is based on the preconception that the genetic and other productivity-affecting properties of soils represent about 90% of the other physical factors controlling the fertility of the habitat. It is expressed in the score range assigned to the soil subtypes. During the further evaluation only those partial ecological effects are taken into consideration which are not represented by soil properties. For instance, the quantitatively evaluable surface water loss due to relief is not reflected in the genetic characteristics of soil, so this effect is represented by a correctional score amounting to only 5 % of the maximum value score of habitat.

The evaluation of the ecological potential in an agricultural area can be approached without emphasizing a dominant factor (like soil) in the productivity of the agricultural habitat. Under different physical geographical conditions on certain cultivated lands different ecological factors may prove to be favourably dominant or restrictive from the viewpoint of crop yield.

That is the reason why - according to this concept - the different types of agroecological factors are provided individually with the customary scores ranging from 1 to 100.

This kind of agricultural environmental assessment results in the areal survey of six main agroecological factors. The factors are referred into 10 categories and supplied with rank scores in a square-grid system representing areal units.

This assessment gives more information than the value score of habitat inasmuch as it provides us with information about the quality of agroecological factors separately. It defines the planning for the necessary interference to ameliorate cultivated land (GÓCZÁN, L. et al. 1979).

Both methods may have two disadvantages from the viewpoint of agricultural users:

- None of them expresses the absolute (economic) value of the arable land, or the way to calculate it.
- None of them gives information concerning the crop-specific relative suitability of land, or the degree of this suitability.

3.4. *A complex land evaluation*

Experiments have been made to remedy of the *first* inadequacy. The *score value of habitat* e.g. (STEFANOVITS, P. et al. 1974) is to represent the contribution of land (one of the factors of cultivation) to agricultural production value. The economic value of land could be calculated if the *value score of habitat* defined the developing ratio of net income in long-term average, or the total value of agricultural production of labour and capital in an unit area. Such an experiment was first conducted by Iván BENET and László GÓCZÁN. As *internationally the first complex land evaluation method,* it made a real land value calculation possible in an economic system where - due to collective land ownership - there is no regulated land market yet. This method defines the *yield quota* (of the cultivated land) from the threefold production result of land-capital-labour with a Cobb-Douglas type production function adapted to 3 independent variables; it considers the gross plant production value as the result variable and the computing the elasticity coefficient for the land represents the land productivity in percentage.

The formula is:

$$y = aF^{\alpha}L^{\beta}K^{\gamma},$$

where

y is the gross plant growing value of a cropland;

F is the cropland score propositioned by the size of the land;

L is the cost of live labour in forints;

K is the cost of capital for each field in forints separately the basic capital (K_1) and the basic capital (K_2);

a is proportion factor

α, β, γ = elasticity coefficients representing the yield-quota of land, labour and capital;

$\alpha+\beta+\gamma = 1$ expressing the volume elasticity of production.

The *land elasticity coefficient* of the correlation matrix solved by the above formula for all the fields of an agricultural farm will give the price of the areal units of the farm if the land elasticity coefficient is weighted by the crop growing value and its capitalized sum by the rate of interest of long-term deposits. Authors chose this land evaluating method because in the socialist economy the transportation expenses - due to uniform prices - do not influence the prize of crops; so there was no need for computing the components of either positional or differential ground rent.

3.5. *Modifications*

The Economic Land Evaluating Council of the Hungarian Academy of Sciences, formed in 1981 for the implementation of the government decree considering the establishment of a new economic land evaluation method, decided to have the economic value of agricultural fields determined by the net income of crop returns and by calculating the differential rent.

The Methodological Committee, formed to introduce the method, accepted Iván Benet's and László Góczán's land evaluation method among several others with a few important changes.

These alterations include, for instance,

- that the net income was accepted in the function as a result variable (instead of the gross plant production value)
- the Benet-Góczán function of 3 independent variables was developed into a function of 5 ones (to indicate the effects of amelioration and irrigation)
- economic data sequences were considered in the correlation matrix instead of data sequences for fields recorded by the farms.

This study is not meant to present the above method in more detail, nevertheless, the first author summarizes his comments to it:

- The account of net income for farms is rendered quite unreliable by the different promotional forms and counter-interests of farms.

- The data acquisition of the 5th independent variable introduced to display the effects of amelioration and irrigation is quite uncertain, and it is only of additional importance composed with the 3 main production factors. The subordination scale of the 4th and 5th variables differs from that of the first 3 ones among one another. Therefore, the interpretation is made unreliable.

- The land elasticity coefficient of the correlational matrix of economic data sequence permits the defining of the average value of farm land and *not the real value* deriving from the quality differences between fields. So the economic land evaluation does not serve its purpose and even shows the false image as if a modern economic land evaluation was established.

- Nor can the differential land rent be defined by this method, as only a reliable ecological regionalization makes the computation of positional land rent possible.

- Our study aims at eliminating the *second* obstacle by the introduced two agricultural environmental assessment methods.

4. AN AUTOMATED ASSESSMENT OF LAND SUITABILITY

4.1. Land evaluation approaches

In international literature (McRAE,S.G. - BURNHAM,C.P. 1981) the following approaches to agricultural assessment of the physical environment (land evaluation) are known. The assessment may be direct, based on crop yields, although in this case we have to consider numerous social and economic factors, too. The indirect approach tries to characterize crop-specific land sutability or land capability for different crops and their relative order through some system of comparison. The actual classification is either based on the threshold value of some important factor (as in the case of category-systems), or on evaluating numerous parameters (parametric systems).

The system introduced in this study is *parametric* (considers the conditions of factors). There are both disadvantages and advantages of such a method. Although parametric systems are quantitative, accurate and specific, easy to apply and simply constructed (in our case for certain crops) but they require multifarious knowledge in the earth sciences (pedological, agroclimatological, geological ets.) so their objectivity and accuracy depends on the exactitude of this knowledge.

The parameters can easily be transformed, changed, increasing perhaps their subjectivity thus to achieve an expected "good" result. One might express a subjective opinion in the language of mathematics. The restrictions should also be considered along with the requirements. One of the main characteristics of such systems is computing a great variety of factors collected into computer data bank. The interactions between factors are imperfectly understood (quantitatively) so their integration is not reliably established either. Land evaluation may serve taxation and regional planning and natural resources surveys very well but, once it is codified legally, it can hardly be changed. It can be applied to the field units of farms although its areal validity is not extensive and it can only be mapped in the form of combined categories. In the parametric systems the score values of factors can either be integrated through addition or multiplication or both. The *additive* method was applied to the investigation of Komárom county although there were multiplicative experiments too which require more reliable data but can show more detailed areal differences (GÓCZÁN, L. - HARNOS, Zs. 1980, SZALAI, L. 1987).

The method to be introduced in the following springs from a three-author study (LÓCZY, D. - TÉCSY, Z. - TÓZSA, I. 1981) written in the Geographical Research Institute Hungarian Academy of Sciences for a competition call. The method of the study has been developed by the authors in several steps (LÓCZY, D. 1982), using a previous soil survey as a primary data base (GÓCZÁN, L. et al. 1969), into a level which might be suitable to achieve the above-stated goal.

It is a new environmental assessment method which classifies the present condition of physical environment (affected by usual agrotechniques) by areal units (in this case 25 hectares) into ten intervals from 0 to 9, from the viewpoint of a given land use (or ecological land capability). The method can be listed among the suitability surveys or site analyses, as cited in English literature (HOWELL, E.A. 1981).

4.2. A brief survey of the method

Once the purpose of assessment is defined, the steps of the suitability analysis are the following (LÓCZY, D. 1982, 1984):

- establishing a computerized data base
- defining and collecting the suitability indices
- elaborating the assessment algorithm and programme
- automated display and printing of the assessment map.

First data have to be acquired concerning the conditions of all agroecological factors which affect crop growing. These data are required to establish the suitability degree of the factors regarding the ecological demands of crops.

Similarly, the ecological demands of the crops to assessed are also to be collected with special concern to the demands in critical periods of their growing seasons.

The third and the fourth steps are executed by a programme writer assistant and a computer.

4.2.1. Computerized data base of assessment

Only a computerized data base can promote an environmental assessment with agricultural viewpoint and enable it to display the ecological suitability for cultivation in an agricultural area in a cadastral survey.

4.2.1.1. The square-grid system for acquiring and storing data

Many factors have to be considered in a studied area to characterize the physical environment. With the help of a dense grid system sufficient data have to be collected on field. These data can be presented on chorograms (adjusted into categories). The information of separate chorograms cannot simply be unified by their superposition, as spatial distribution patterns vary with different factors. The areal validity (extension) of field data is limited according to the professional experience of the investigator. The inaccuracy emerging from this fact cannot be neglected even with the most experienced mapmakers. Therefore, when superposing chorograms, the border lines of units may separate such areal units which, in reality, are hardly different from the neighbouring ones. The lucidity of integrated maps is rather bad due to their fragmented appearance. This potential error is increased if the superposed chorograms are constructed from maps of various scales through enlargement or reduction (as it often happens though in data acquisition).

The solution can be a simple, constant reference basis independent from the spatial distribution of physical factors, which can "unify" numerous chorograms. A standard square-grid system (KLINGHAMMER, I. - PAPP-VÁRY, Á. 1973) can be imposed on every chorogram and the coincident square units of all factors can be referred to the same way. The *square-*

grid data acquisition, storage and retrieval system meets the above requirements. As every method, with its advantages, it has its disadvantages too. The border lines of different qualities are approximative. Consequently, they are rather inaccurate on the square-grid map. However, the lines of the grid function as border lines concerning parameter values and the spatial distribution of several factors and the position of a square can easily be recognized. By placing the grid system upon the chorograms, they can be digitized without difficulty extending the dominant figure (quality) throughout the whole square unit. A figure is written into each unit of the square-grid. The data matrix of an adquately detailed square-grid can reflect the spatial distribution of factors reliably. The scale depends on the survey goal and the density of the data available. The areal units can be identified by indicating the rows and columns with figures or letters. The origin of such coordinate system is arbitrary but in the case of a national survey it can be made uniform. One of the disadvantages of the square-grid system is its inaccuracy compared to ordinary maps, and that exact areal extensions cannot be calculated from them. The approximate size of areas can easily be seen and defined by summing up the square units.

Used as overlays, the grid maps even increase the minor inaccuracies of the chorograms and the 'border effect', known from the interpretation of satellite images, can be observed (i.e. false results appear along the margins of homogeneous areas).

4.2.1.2. A computer compatible data base

When all the required, digitized maps are brought together in a square-grid map sequence, the uniform data file can be stored in computer memory.

Not all the chorograms used in environmental assessment, however, are based on numerical information. The chorograms of the parent rock or land use do not show figures but various qualities (like loess, sand or meadow, settlement, etc.). The categorized numerical data and the qualities identified with names can only be stored in a uniform way with the help of coding. The possible conditions of the chosen physical factors in Hungary are represented by code numbers in some logical order. The II.10/10 symbol means the 10th factor (e.g. the temperature total for October expressed in °C) and its 10th condition (331-340°C); and similarly the III.20/10 symbol means the 20th factor (e.g. physical soil type) and its 10th condition (sand soil), which are not numerical conditions.

A code often represents the combined conditions of factors. In such cases a coding table is needed to encode the conditions or qualities. Actually, the data base should not only record the conditions of isolated factors, but at least the most important interrelationships too. The factors closely related to each other can be stored together in the memory also saving computer running time thereby.

The method has to meet the requirements of data storage and retrieval, because the multifactoral assessment of the physical environment needs such large amount of data that can only be handled by computer. After having the assessment programme run, the plotter of the computer can print the assessment 'map' derived from data base, in the form of a data matrix similar to the form of the stored data files. The synchronous printing of the code numbers of a factor or two is possible if we want to compare them. Mathematical statistical relationships can also be computed between them.

Figure 1 shows the data base set up of superimposed square-grid maps.

The code numbers of the factors required for the assessment are present in the data base. Apart from the extent of the area to be assessed, two conditions define the size of the data base: all important factors should be present (codes have to be assigned to all of their states occurring in Hungary even if they are not to be found in the investigated area), and the properly detailed data of the factors should be accessible either on thematic maps or through simple field investigation.

A data base compiled for a given assessment goal can be used partially or as a whole for an assessment with a different goal. (Supposing the data are sufficiently detailed from the viewpoint of the new goal./ To ensure this, no assessment score should be assigned to the stored codes. The data base (i.e. the area portrayed by the coded parameters) has to be assessed by a computer programme. This programme is to be changed as necessary with the changing goal. The data base is supplemented with the codes of the new factors. The judgement of the old elements often changes in the new programme. If, for instance, the 6/11 (the 11th condition of the 6th factor) was "good" in one assessment, It may, in turn, be "restrictive" in another.

The data base is increased with the addition of new assessment goals, reflecting the physical environment more and more comprehensively (although never in an exhaustive manner).

The superimposed square-grids illustrate the digital storage of the conditions of environmental factors.

4.2.2. Identifying suitability indicators

Whatever the purpose of the environmental assessment should be, its efficiency is basically influenced by the rate of accurate and unambiguous definition of the requirements set up by the economic branch utilizing the physical environment. One of the viewpoints in constructing the data base is the factor to which the utilizing economic branch or other activity is the most sensitive. The user itself should 'hand in' the list of the favourable and unfavourable conditions which limit the suitability of the surveyed area from the viewpoint of the assessment goal.

The data base is the 'supply' side of environmental assessment, while the requirements of the user constitute the 'demand'. The link between them is the sequence of the *suitability indicators*. Their task is to confront the demands and the endowments of the area on the level of well-defined, elementary environmental conditions. The conditions of the environmental factors are actually categorized by the suit-

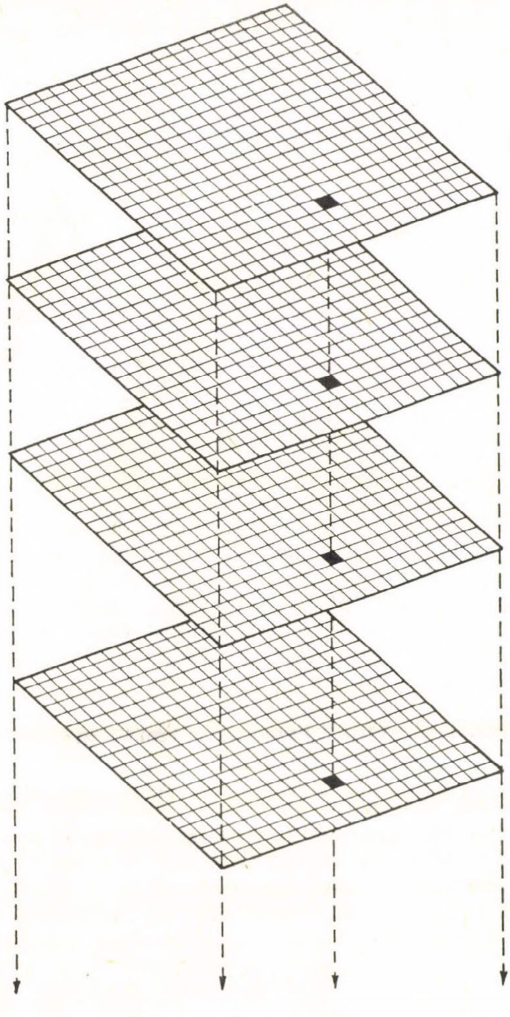

Fig. 1 Composition of the data base

ability indicators. The conditions may be *excellent, very good, good, neutral or medium, moderately restrictive, restrictive, very restrictive or unsuitable* (disqualifying).

There is no need to make a distinction between the "neutral" and "medium" grades of conditions. From the ultimate, integrated assessment of the environment it is insignificant whether certain conditions are not taken into consideration at all in the suitability survey of the area, or if they allow cultivation at a level equal to the national average yield and quality of the crop in question. In this case they are of neither positive nor negative influence to the final outcome of the assessment.

Regarding their contents, the suitability indicators are correlations between (quasi)elementary environmental conditions and suitability grades. They can be listed in tables from which we can learn how the coded conditions meet the demands set up by environmental management. E.g.:

factor no	excel-lent	very good	good	medium	moderate-ly re-strict-ive	restrict-ive	very restrict-ive	unsuit-able
19	3	4	2	6	5	1	7	-

Here the 6th condition of the 19th factor is judged to be neutral or of medium quality and, thus, it does not influence the evaluation.

The 'unsuitable' label does not automatically mean complete overall unsuitability. The assessment programme has to be designed to assess an unit where an unsuitable condition occurs, worse than neutral.

The grades of suitability can naturally be increased depending on the completeness of the list reflecting the users' requirements. The above table with eight classes (including the 'neutral' classification) seemed to be sufficient for an experimental run of the method.

We do not have to find suitability indicators for every environmental condition, and, similarly, we do not have to consider every factor for each assessment goal.

After making up the list of suitability indicators we have to mark those factors which are to be emphasized in the automated assessment, according to their prominence in the total environment. These are the climatic parameters for critical months or the most compound, complex of factors, the genetic type of soil. The rate of weighting (twofold or fourfold) in the assessment programme, has to be decided from experience.

4.2.3. Assessment algorithm and programme

Having enlisted all the important conditions of all the important factors into suitability rates by the classification of code numbers, and having both the data and the suitability indicators in the input data, we have given the computer all the necessary information to complete the assessment. From now on the environmental assessment can be fully automated.

The *assessment algorithm* contains the steps of mathematical data processing. It means the order of comparing all the units of the data base codes to the suitability indicators. A programme is written on the basis of the algorithm in some computer language (in our case in BASIC). It orders the computer to assess each unit. According to the suitability category to which each localized condition (code number) belongs, the programme marks the units with scores from +3 to -12. Having repeated the procedure for each factor it considers their weighting and adds up the figures. The resulting series of figures from the small to the greater numbers are subsequently categorized from 0 to 9. These scores are assigned to the areal units, they are the *rank scores* representing the final score of the units.

0 means that the areal unit is unsuitable for the given specified utilization and 9 represents the best under the conditions of Hungary. The other scores are proportional to the dgrees of relative suitability.

4.2.4. Ecological suitability plotted by computer

Having assigned a rank score (from 0 to 9) to each areal unit, the computer plots the environmental assessment matrix with the help of the coordinates of the areal units. The intervals of printed figures can be fixed so that the figures should match into a square-grid of the desired size. This way we can obtain a digitized 'grid map' of similar scale to that of the data matrix. However, the vertical scale cannot perfectly be adjusted to the horizontal one.

We can render our 'map' more expressive by colouring the squares according to the figures (e.g. from the cold colours towards the warmer) and we can demonstrate increasing suitability through this. Figures make the mathematical interpretation easier, while displaying in colour promotes the visual one.

5. THE SCALE OF ASSESSMENT AND LIMIT OF AREAL ERROR

Any land evaluation with agroecological purpose has to observe the interests and conditions of agriculture. In crop cultivation the smallest unit is the field so, in theory, data collection and evaluation have to have areal units smaller than the smallest field. Farming units may also be interested in the differences within the area of a single field actually. The smaller the units are, the more precisely the fields can be displayed in the 'square-grid maps'. In the case of land suitability for the area of one farm, surveying a few dozen hectare fields, the squares cannot be larger than 10 ha. Since this detail, if applied to several thousand sq. km areas, would not be maintained on a personal computer, a reduced scale had to be found.

In our expriment the scale was 1:25,000 which means 25 ha squares, using sq. cm units in the printed square-grid system. The data sources available for the present study enable us to use this scale.

When digitizing the maps, we have to be aware of the following *sources of error:*

a. The size and shape of an area spot changes on the square-grid map. The error depends on the positioning of the square-grid. However, the difference is not very significant, it is about 5% with an area larger than 100 hectares. The increases and decreases for individual fields level each other out in the end product.

b. Areal units, smaller than half of the square-grid (ca 15 hectare) can be neglected. The square-grid 'map' is naturally more generalized than an ordinary chorogram.

c. "Averaging" the conditions of environmental factors (which is necessary to digitize map content square by square) is more difficult when we consider land qualities as genetic type of soils, or parent rock than we consider 'quantitative states' (as slope category and soil pH). When a square is located on the boundary of two different areas of a map it is difficult to decide the code to be assigned to the square. The error can be decreased if this situation is repeated so that we can take turns in digitizing the conditions. This way the proportion does not change over larger areas *(Fig. 2)*.

d. The also manifest 'border effect' has already been described.

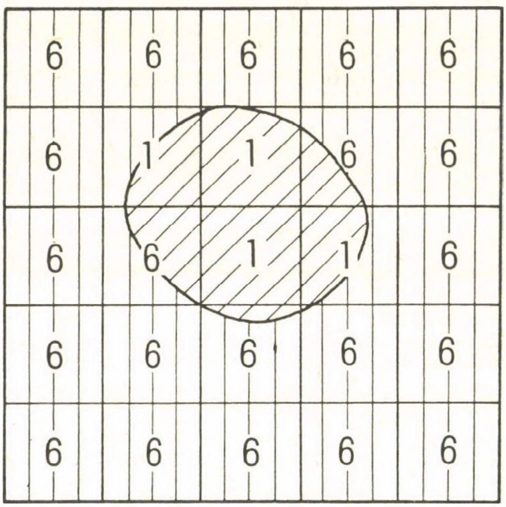

Fig 2 Coding environmental conditions (example: parent rock) differing in quality.

1 = code for sand; 6 = code for clay. Areal error is + 4.2 per cent

Somewhat simplifying the previously applied system (LÓCZY, D. 1984), we selected 21 environmental factors *(Table 1)* for the land suitability survey. We studied the very detailed spatial distribution of 6 of them. The areal error limit of the whole data base is estimated at not more than 10 per cent.

Table 1 The parameters coded in the data base of land capability survey

I. RELIEF

1. Slope category /primary and secondary/+ degree of terrain dissection + /for slopes steeper than 17 per cent/ slope exposure /primary and secondary/

II. CLIMATE

2. Temperature total for March
3. Temperature total for April
4. Temperature total for May
5. Temperature for June
6. Temperature for July
7. Temperature for August
8. Temperature for September
9. Temperature for October
1o. Average precipitation for May
11. Average precipitation for June
12. Average precipitation for July
13. Average precipitation for the period April to September
14. Average precipitation for the period May to September
15. Average precipitation for the period May to August
16. Average precipitation for the period March to June

III. SOILS

17. Genetic soil type + organic matter content of humic layer
18. Parent material + soil depth
19. Texture
2o. Soil reaction /pH/ and occurrence of $CaCO_3$
21. Groundwater depth + permeability

6. SELECTION OF PARAMETERS REPRESENTING THE PHYSICAL ENVIRONMENT FOR THE LAND SUITABILITY SURVEY

In our experiment we assumed a similarity in the ecological needs of cultivated crops inasmuch as they require the same environmental elements (heat, light, water, etc.). Thus, only a limited number of physical environmental factors have to be considered to describe the significant properties of a 'good' or a 'poor' habitat.

At the same time, different crops need different conditions of these factors as favourable or restrictive. Different areas are likewise suitable for the cultivation of a certain crop to various degrees. With the simultaneous evaluation of several factors, not only the suitable or unsuitable areas are traced but some degrees of suitability are also defined.

Describing land suitability was first set as a goal in a soil survey (KREYBIG, L. 1937, pp. 6-7.): "The volume (financial value) of the investment required by the largest possible yield and by the needs of different crops defines the production value of soils."

"If we want to decide which *agricultural production system* * and method can be applied the most successfully ... we have to know the *ecological needs of plants*, the most important *soil properties*, the *climate* and the *weather* and all the *laws of nature* prevailing in the relationships between soil and plant life."

This quotation emphasizes the relationship between the ecological value of the agricultural habitat and the applied agrotechnique and profitability.

G. GÉCZY conducted a national soil use mapping in 1957-1968. Its purpose was to find the crops with the highest suitability for certain soil types. The endowments of agricultural habitats were referred to five grades according soil use groups (GÉCZY, G. 1965).

The present system, which heavily relies on previous research (including the land evaluation project), identifies 8 classes "excellent, very good, good, medium, moderately restrictive, restrictive, very restrictive, unsuitable" and refers environmental conditions to them according the degree to which they meet the ecological demands of crops. In practice, it means the increase or decrease of national average yields at a uniform level of agrotechnology, caused by the environmental conditions in question.

If data from experiments were available on the relative significance of individual physical factors in crop development about their influence on crop yields and quality, the present relative rating could be made more sophisticated through increasing the number of classes. Theoretically, it is feasible to determine ecological requirements in experiments (see, for instance, TEACI, B. - BURT, M. 1964). The impact of each factor judged important would be measured against the average conditions of other factors. (The principles and stages of agrometeorological and phenological observations are described by VARGA-HASZONITS, Z. 1977.) The interactions between factors could also be revealed in more detail. If the results of experimentation, i.e. the crop yields were plotted against various parameters investigated on a chart, a more objective foundation could be given to the suitability indicators *(Fig. 3)*.

However, until such detailed empirical findings are available, the information gathered from literature (which is occasionally ambiguous or even contradictory) have to be relied on, (see Bibliography).

The main groups of ecological requirements according to sources in literature are

a) certain relief parameters;

b) agroclimatological elements;

c) soil properties.

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* Simply meaning the way of cultivation. The term was not conceived in its modern sense at that time. (L.D.)

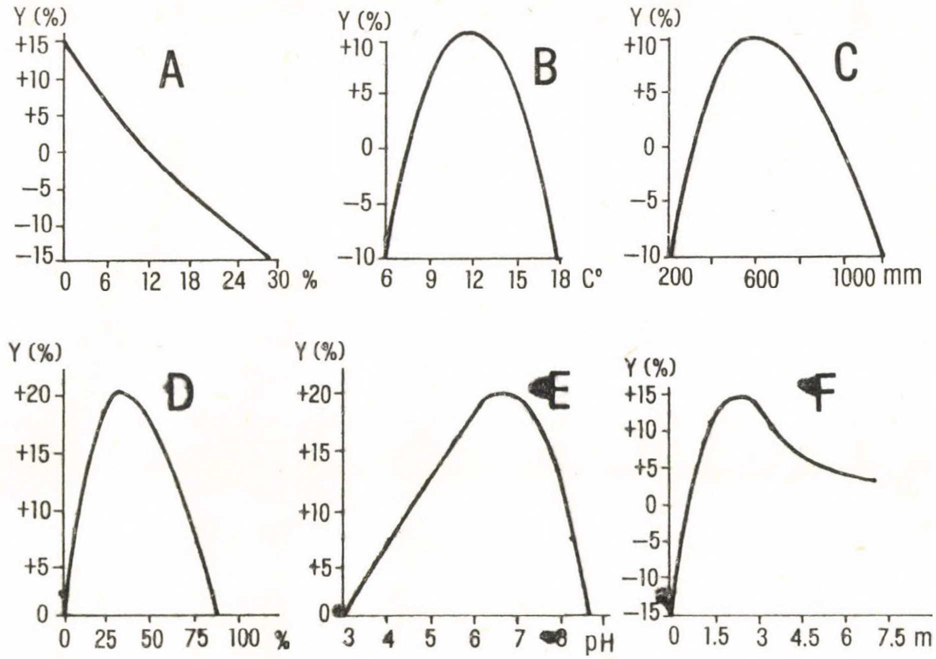

Fig. 3 Empirical curves used in the Romanian parametric land classification system. (After TEACI, D. and BURT, M. 1974).

A = slope (%); B = mean temperature for the growing season (°C); C = Average rainfall for the growing season (mm); D = clay content of soil (%); E = pH; F = Depth to groundwater table (m)

Although the relative significance of these three groups of factors varies with plants, it is not relevant to our task in agricultural land capability studies what we have to do is to elaborate *relief*, *climatic* and *soil* parameters and include their conditions in the data base.

6.1. Topography

The relief is best described synthetically by the general category 'landform'. Its analytical description involves several morphometric parameters: altitude above sea level, slope inclination and exposure, horizontal dissection and so forth. These parameters all influence agroecological conditions to various degree but seldom directly. Landscape geographical research in Czechoslovakia (MAZÚR, E. et al 1981) has had remarkable achievements in ecological relief assessment based on morphometric parameters. In Australia the relief of more extended areas are assessed by "terrain units" for a variety of purposes (ARNOT, R.H. - GRANT, K. 1981). The methods elaborated in Hungary for the assessment of the physical environment start with landform but also employ morphometric parameters (PÉCSI, M. 1979b; GÓCZÁN, L. 1984).

In the method for determining land suitability for crop cultivation a less complicated approach should be adopted. Not more than a single relief factor can be included unless relief were overemphasized in the end product of the assessment. Additional factors would be unnecessary overburden for the data base and would finally make computer processing uneconomical.

Landform elements have significance, first of all, in three respects: they influence microclimate, control soil depth and the position of groundwater table. The last two are considered with the soil properties, but the microclimatic influence, in lack of microdynamic data, has to be taken into account when assessing relief. Landforms build up of slopes and flat surfaces; describing them by parameters is equivalent to giving them names. Consequently, the relief factor employed in the system is based on *slope inclination* and, in the case of slope angles above 17 per cent, complemented with *slope exposure*. Since the areal units of the microregional subdivision survey were larger than previously (25 ha squares), secondary slope inclinations and exposures were also taken into account. The percentage slope categories equal to the classes generally applied in agriculture (ERÖDI, B. - HORVÁTH, V. 1965). The requirements of agrotechnology, mechanization are reflected in the classes. Eight points of the compass were differentiated in a grouping accordant with microclimatic influence (S and SW; W, E, SW and SE; N and NE).

The coding of relief conditions is presented in *Table 2*.

In the assessment of relief vertical dissection (relative relief), although important mainly in agrotechnology, was neglected. Field cultivation in Hungary is limited to a rather narrow altitudinal zone (ca 80-350 m above sea level). Within that, slope category is the most important cause of variation.

As a matter of course, topography reappears in the assessment with soil properties, the map representations of which are adjusted to relief (particularly in the case of the depth of humus layer - parameter no 18 in *Table 1*).

Minor relief is able to exert a decisive influence on soil formation and erosion. The independence of the relief factor is, therefore, relative, as it is bound to other factors at the various stages of the assessment procedure.

6.2. Climate

In our method climate is assessed at macro and mesolevels. It would be too expensive to carry out microclimatic measurements of proper detail (photosynthetically active radiation, soil temperatures at various depths, etc.), but further improvement of the evaluation would inevitably call for the data of representative test areas (JAKUCS, P. - MAROSI, S. - SZILÁRD, J. 1969) and their extension through analogy.

At present, the most direct climatic modification by relief should appear clearly (see above at the relief factor). Applying the long-term observation theories of meteorological basic stations through interpolation with regard to physico-geographical principles, reliable data can still be gathered

Table 2 Coding table for factor I. 1/Relief/

Subordinate slope category % >25: S SW	>25: W E SE NW	>25: N NE	17 - 25: S SW	17 - 25: W E SE NW	17 - 25: N NE	12- -17	5- -12	0- -5	none	Predominant slope exposure	Dissection m/25 ha	Predominant slope category %
				1					2		0	0- -5
				3					4		1-500	
				5					6		500-1000	
				7					8		>1000	
		9						10	11		0	5- -12
		12						13	14		1-500	
		15						16	17		500-1000	
		18						19	20		>1000	
21	22	23	21	22	23		24		25		0	12- -17
26	27	28	26	27	28		29		30		1-500	
31	32	33	31	32	33		34		35		500-1000	
36	37	38	36	37	38		39		40		>1000	
41	42	43					44		45	N,NE	0	-17- 25-
46	47	48					49		50	W,E,SE,NW		
51	52	53					54		55	S,SW		
56	57	58					59		60	N,NE	1-500	
61	62	63					64		65	W,E,SE,N,W		
66	67	68					69		70	S,SW		
71	72	73					74		75	N,NE	500- -1000	
76	77	78					79		80	W,E,SE,N,W		
81	82	83					84		85	S,SW		
86	87	88					89		90	N,NE	>1000	
91	92	93					94		95	W,E,SE,N,W		
96	97	98					99		100	S,SW		
			101	102	103	149			104	N,NE	0	>25
			105	106	107	150			108	W,E,SE,NW		
			109	110	111	151			112	S,SW		
			113	114	115	152			116	N,NE	1-500	
			117	118	119	153			120	W,E,SE,NW		
			121	122	123	154			124	S,SW		
			125	126	127	155			128	N,NE	500-1000	
			129	130	131	156			132	W,E,SE,NW		
			133	134	135	157			136	S,SW		
			137	138	139	158			140	N.NE	>1000	
			141	142	143	159			144	W,E,SE,NW		
			145	146	147	160			148	S,SW		

for areas of some dozens of sq. km (for arbitrarily delimited areas as the administrative areas of villages).

Originally, we attempted to break down the agroecological significance of climate to its three major components, the dominant climatic factors: radiation, temperature and water budget, since the degree to which the energy and water demands of plants are mapped is a primary indicator of land capability (VARGA-HASZONITS, Z. 1977).

The method for identifying climatic regions by the value of energetical potential production (the amount of carbohydrates produced at 5 per cent efficiency level of photosynthetically active radiation - elaborated by SZÁSZ, G. 1979) was abandoned and not included among the factors controlling land suitability, since it itself involves regionalization.

In the agroecological literature the temperature and water requirements during the growing season of cultivated crops are indicated. The indicators for the whole growing season are not informative enough to be used in land suitability investigations, since if a crop requires 2600 to 2900 °C temperature during its growing season, it does not mean more than the mentioned crop can be cultivated safely in Hungary. However, in the development of each plant species there are one or more periods when the plant is particularly responsive to the factor of the external environment, including climate. The temperature requirements of crops are only considered during these periods termed critical in agrometeorology. In agroecology the critical periods (phenophases) are approximated by two-week on ten-day spells (decades). In land suitability studies this detail cannot be attained, since data can only be gathered for months (and long-term averages are also calculated for months). Consequently, the *temperature of the critical months of the growing season* (from March to October) are analysed and included in memory *(Table 3)*.

There are critical months of the water supply of plants too and monthly rainfall figures also appear in the data base coded according to *Table 4*.

To allow for total precipitation during the growing seasons of root crops, various perennial crops and winter cereals, additional parameters were included.

Available moisture from precipitation depends on runoff, infiltration and water capacity conditions. Runoff is regarded approximately proportional to slope category and, therefore, was not considered again. Infiltration is a function of soil permeability. Soil texture classes are regarded to ensure reliable coding.

Some agroclimatic indicators of lesser importance (wind directions and velocity, cloudiness, vapour pressure, winter temperature and precipitation) were not included into the assessment at all. The remark should be made here that in the land suitability analyses for the cultivation of certain crops (for instance grapevine or fruit-trees) the incorporation of other climatic elements (as frost hazard) cannot be avoided.

The extremities of *weather* are even more effective on plant development than climate. Although the assessment of weather is outside the scope of the present system, a future perspect-

Table 3 Coding table for factors II. 2-9./Temperature totals for the months of the growing season/

Temperature totals /^{o}C/

Factor no								
2	3	4	5	6	7	8	9	Code
Months								
III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	no
<100	<200	<350	<450	<550	<500	<400	<250	1.
101-110	201-210	351-360	451-460	551-560	501-510	401-410	251-260	2
111-120	211-220	361-370	461-470	561-570	511-520	411-420	261-270	3.
121-130	221-230	371-380	471-480	571-580	521-530	421-430	271-280	4.
131-140	231-240	381-390	481-490	581-590	531-540	431-440	281-290	5.
141-150	241-250	391-400	491-500	591-600	541-550	441-450	291-300	6.
151-160	251-260	401-410	501-510	601-610	551-560	451-460	301-310	7.
161-170	261-270	411-420	511-520	611-620	561-570	461-470	311-320	8.
171-180	271-280	421-430	521-530	621-630	571-580	471-480	321-330	9.
181<	281-290	431-440	531-540	631-640	581-590	481-490	331-340	10.
	291-300	441-450	541-550	641-650	591-600	491-500	341-350	11.
	301-310	451-460	551-560	651-660	601-610	501-510	351<	12.
	311-320	461-470	561-570	661-670	611-620	511<		13.
	321-330	471-480	571-580	671-680	621-630			14.
	331<	481-490	581-590	681<	631-640			15.
		491-500	591-600		611-650			16.
		501<	601<		651-660			17.
					661<			18.

ive exists starting from the frequency of year types of different weather conditions (atlantic, continental or mediterranean). A comparison of the national and regional (for the test area of Komárom county) frequency values is shown in *Figure 4.*

6.3. Soils

While mesoclimate is uniform over large surfaces, soil endowments are distributed in a mosaical fashion. Soils are the most diverse components of the physical environment.

Soil surveys apply numerous parameters to portray the soil conditions of an individual area. The maps produced

Table 4. Coding table for factors II.lo-16. /Average precipitation for May,June,July, for the periods April to September, May to, September, May to August and March to June/

Precipitation /mm/

Factor no							
1o	11.	12.	13.	14.	15.	16.	
M o n t h s							Code
V.	VI.	VII.	III-VI.	IV-IX.	V-VIII.	V-IX.	no
<35	<45	<55	<18o	<31o	<23o	<27o	1.
36-4o	46-5o	56-6o	18o-19o	311-32o	231-24o	271-28o	2.
41-45	51-55	61-65	191-2oo	321-33o	241-25o	281-29o	3.
46-5o	56-6o	66-7o	2o1-21o	331-34o	251-26o	291-3oo	4.
51-55	61-65	71-75	211-22o	341-35o	261-27o	3o1-31o	5.
56-6o	66-7o	76-8o	221-23o	351-36o	271-28o	311-32o	6.
61-65	71-75	81-85	231-24o	361-37o	281-29o	321-33o	7.
66-7o	76-8o	86-9o	241-25o	371-38o	291-3oo	331-34o	8.
71-75	81-85	91-95	251-26o	381-39o	3o1-31o	341-35o	9.
76-8o	86-9o	96-1oo	261-27o	391-4oo	311-32o	351-36o	1o.
81-85	91-95	1o1-1o5	271-28o	4o1-41o	321-33o	361-37o	11.
>86	96-1oo	>1o6	281-29o	411-42o	331-34o	371-38o	12.
	1o1-1o5		>291	421-43o	341-35o	381-39o	13.
	>1o6			431-44o	351-36o	391-4oo	14.
				441-45o	361-37o	4o1-41o	15.
				451-46o	371-38o	411-42o	16.
				461-47o	381<	421-43o	17.
				471-48o		431-44o	18.
				481-49o		>441	19.
				491-5oo			2o.
				>5oo			21.

are, in many respect, the repetition of each other. If all were equally incorporated in the assessment, certain soil properties would appear multifold in the end product and, thus multiple assessment, a major danger of assessment methods, cannot be avoided. Each of the properties should be taken into consideration only once unless they are evaluated from different viewpoints (e.g. soil texture for root development or capillary water motion). The soil factors are coded as shown in *Tables 5-9.*

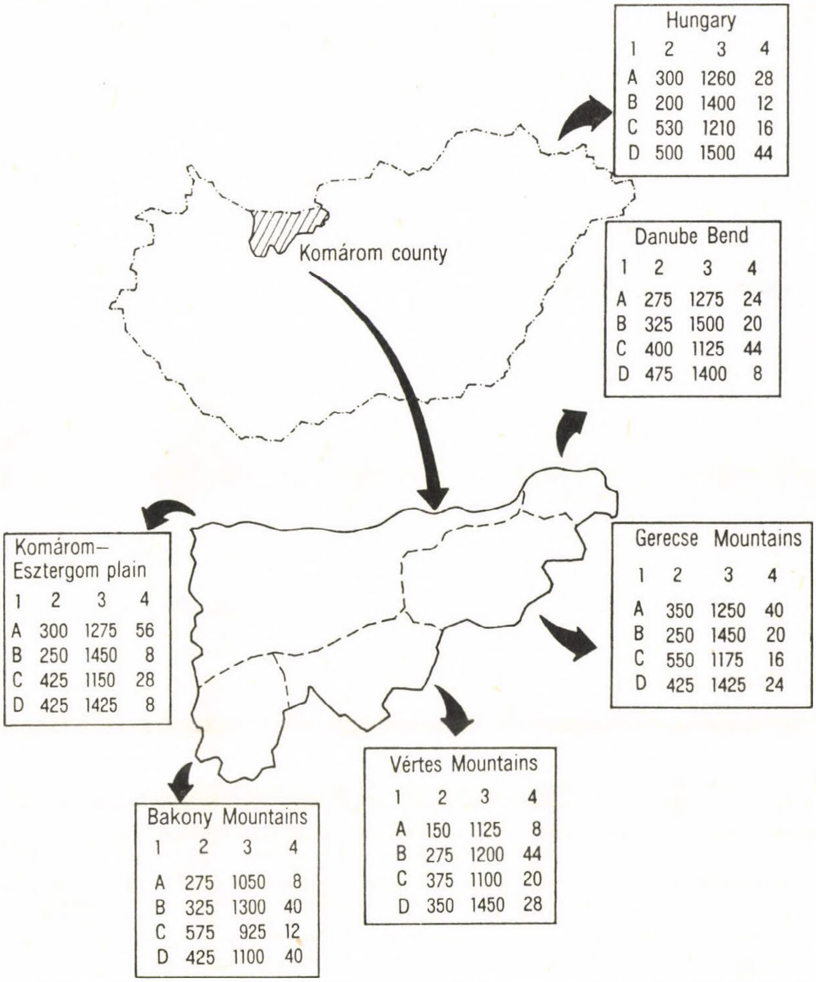

Fig. 4 Frequency of climatic year types for Komárom county and for Hungary (After LÁNG, I. - CSETE, L. - HARNOS, Zs. 1983).

1 = climatic year type; 2 = precipitation of the growing season (mm); 3 = temperature total of the growing season (°C); 4 = frequency of climatic year type (%)

In the first place the *genetic soil types* and *humus conditions* are included among the pedological factors. The first attaches a dynamic character to the data base since the genetic typology of soils in Hungary (STEFANOVITS, P. 1981) is founded on the presence and intensity of soil forming *processes*. Humus conditions comprise the depth of humus layer (in cm) and percentage humus content. The generally applied handbook of soil survey (SZABOLCS, I. ed. 1966) defines categories for the depth of humus layer (shallow, medium or deep) and for humus content

Table 5 Coding table for factor III.17 /Genetic soil type and organic matter reserves/

Genetic soil type or variety	organic matter reserves /tonnes per hectare/					
	-5o	5o-1oo	1oo-2oo	2oo-3oo	3oo-4oo	4oo-
Skeletal soils with stones or boulders	1					
Skeletal soils with gravels	2					
Barren earth'+	3					
Blown sand soils	4					
Humic sand soils	5					
Humus carbonate'soils++			6			
Rendzinas	7	8	9	1o	11	
Erubase soils		12	13	14	15	16
Heavily acidic, non-podsolic brown forest soil	17	18	19			
Podsolic brown forest soil	2o	21	22	23		
Lessivated brown forest soil	24	25	26	27		
Pseudogleyic brown forest soil	28	29	3o			
Ramann's brown forest soil	31	32	33	34		
Brown forest soil with 'kovárvány'+++	35					
Brown forest soil with retained carbonate	36	37	38	39		
Chernozem brown forest soil	4o	41	42	43		
Chernozem soil with forest	44	45	46	47	48	
Leached chernozem soil	49	5o	51	52	53	54
Pseudomycelial chernozem	55	56	57	58	59	
Meadow chernozem soil		6o	61	62	63	64
Terrace chernozem soil	65	66	67			
Solonchak	68					
Solonchak-solonetz	69					
Meadow solonetz	7o					
Meadow solonetz with chernozem dynamics			71			
Secondary alkali soil	72					
Solod'	73					
'Anthropogenic humus carbonate'++++	74	75	76			
Sandy meadow soil with solonchak	77	78				
Clayey meadow soil with solonchak			79	8o		
Sandy meadow soil with solonetz	81	82				

Table 5 /continued/

Genetic soil type or variety	organic matter reserves /tonnes per hectare/ -50	50-100	100-200	200-300	300-400	400-
Clayey meadow soil with solonetz			83	84		
Sandy meadow soil	85	86				
Clayey meadow soil			87	88		
Sandy alluvial meadow soil	89	9o				
Clayey alluvial meadow soil		91	92			
Sandy boggy meadow soil			93	94		
Clayey boggy meadow soil					95	96
Sandy chernozem meadow soil		97	98			
Clayey chernozem meadow soil				99	1oo	
Meadow bog soil				1o1	1o2	
Peat bog soil					1o3	
Drained and cultivated meadow bog soil					1o4	
Soil of swamp and flood plain forests	1o5					
Fresh alluvium	1o6					
Humic alluvium	1o7					
Slope deposit soils	1o8	1o9	11o			

+ Embrionic soil formed on sediments exposed by erosion

++ Soils with relatively high humus content formed on eroded unccnsolidated rocks

+++ With alternating strings of clay substance/'kovárvány'/

++++ Soil with humus content increased by cultivation

Table 6 Coding table for factor III. 18 /parent material + soil depth/

Parent material	Soil depth /cm/				
	0-20	20-40	40-70	70-100	100-
Loess /typical,slope and sandy/	1	2	3	4	5
Lowland and floodplain loess, loessy silt	6	7	8	9	10
Calcareous fine medium grained sand	11	12	13	14	15
Non-calcareous fine grained sand	16	17	18	19	20
Cover sand	21	22	23	24	25
Clayey sand	26	27	28	29	30
Clayey sand with slope debris	31	32	33	34	35
Calcareous coarse sand	36	37	38	39	40
Non-calcareous coarse sand	41	42	43	44	45
Calcareous gravelly sand	46	47	48	49	50
Non-calcareous gravelly sand	51	52	53	54	55
Calcareous blown sand	56	57	58	59	60
Non-calcareous blown sand	61	62	63	64	65
Calcareous silty sand	66	67	68	69	70
Non-calcareous silty sand	76	77	78	79	80
Gravelly-silty sand with rock debris	81	82	83	84	85
Calcareous silt	86	87	88	89	90
Non-calcareous silt	91	92	93	94	95
Calcareous sandy silt	96	97	98	99	100
Non-calcareous sandy silt	101	102	103	104	105
Calcareous sandy clay	106	107	108	109	110
Non-calcareous sandy clay	111	112	113	114	115
Paludal and meadow clay Heavy clay	116	117	118	119	120
Gravel and debris layer, mountain-foot rock debris	121	122	123	124	125
Cemented gravel layer	126	127	128	129	130
Paludal calcareous bed,	131	132	133	134	135
other calcareous material	131	132	133	134	135
Volcanic tuffs	136	137	138	139	140
Shale	141	142	143	144	145
Marl	146	147	148	149	150
Solid rocks	151	152	153	154	155

Table 7 Coding table for factor III. 19 /soil texture/

Sand	1
Sandy loam	2
Loam	3
Clayey loam	4
Clay	5
Peat, decomposed peat	6
Stony skeletal soil	7

Table 8 Coding table for factor III. 20 /soil reaction and $CaCO_3$ conditions/

Strongly acidic soils /pH 5.6/	1
Slightly acidic soils /5.6 pH 6.6/	2
Neutral to slightly alkali soils /6.6 pH 8,6/	3
Alkali soils with $CaCO_3$ occurring at depth	4
Alkali soils with $CaCO_3$ in topsoil	5

Table 9 Coding table for factor III. 21 /groundwater level/

Arany's cohesion index[1]	Average depth to groundwater table /m/			
	-2	2-3	3-5	5-
-25 /sand/	1	2	3	4
26-35 /sandy loam/	5	6	7	8
36-42 /loam/	9	10	11	12
43-50 /clayey loam/	13	14	15	16
51- /clay/	17	18	19	20
stony soils, peat	21	22	23	24

[1] An empirical index based on soil texture

(low, medium or high) by genetic soil types. In the present variety, humus conditions are represented by organic matter reserves in tonnes per hectare, the codes for factor No 17 contain the essential information of genetic soil type combined with organic matter and, in addition, soil texture can also be deciphered for some of the soil types (where it is relevant).

The availability of nutrients artificially (as manure and fertilizer) added to the soil, the degree of erosion or erodibility of topsoil and other circumstances are highly dependent on the humus conditions. The genetic soil type and humus conditions as comprehensive factors are directly associated with almost all other factors *(Fig. 5)*.

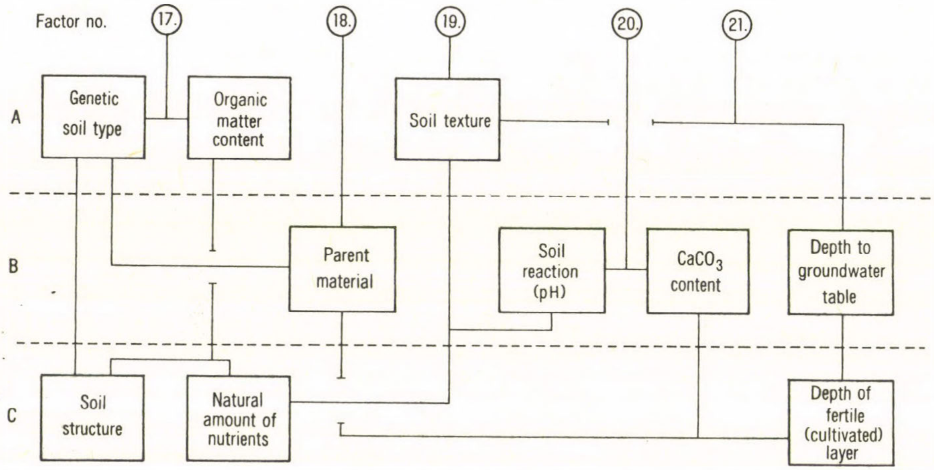

Fig. 5 Interrelationships of soil properties and their coding.

A = primary properties; B = secondary properties; C = properties indirectly included

Regarding their function, among others, in water storage and in the restriction of the depth of tilth, the detailed and separate assessment of *soil parent materials* is justified. Near-surface rocks are coded with their *depth of occurrence* by the accepted limits of the depth of tilth (GÉCZY, G. 1968). Distinctions are drawn between rocks with or without $CaCO_3$ content the codes reflect whether $CaCO_3$ content exceeds 20 per cent and reduces the depth of tilth (if the calcareous horizon occurs at less than 1 m depth). The reduction of the fertile layer may also be attributed - among others - to compact, intact rocks, gravel or heavy clay horizons.

Besides its ecological significance (the influence on root growth and aeration), *soil texture* and structure are also important in agrotechnology and to be considered at the decisions concerning the techniques of cultivation. Soil texture is coded by broad categories as 'physical soil types'. They are usually identified and mapped during soil surveys. Although the interpretation of the terms applied here (sand, loamy sand and like) varies with countries (HODGSON, I.M. 1978), their practical implications can be regarded more or less the same.

Another combined factor is included in the assessment. Here two evaluated soil properties, *$CaCO_3$ content* and *pH* (soil reaction), are studied in combination. Starting with KREYBIG, L., the sources in literature classify plants according to their requirement for pH: species favouring acidic or calcareous soils and those non-susceptible to $CaCO_3$ are distinguished. Since pH can be easily altered by agrotechnic interference, its categories are rather broad.

The empirical correlation between $CaCO_3$ content and pH is quite weak. To describe $CaCO_3$ content, the value for the topsoil was coded combined with pH. $CaCO_3$ content above 20 per cent restricts the depth of the fertile layer. If the topsoil is free of carbonates, a category of deeper occurrence for $CaCO_3$ was included in the data base and assessed for land suitability.

The insufficient nation-wide data base (at 1:100,000 scale) presented the application of the more sophisticated categories we had experimented with earlier.

Soil texture already treated controls infiltration intensity and velocity. Plants, however, are supplied with moisture not only directly from atmospheric water but also from *groundwater. Maximum groundwater table* and its range are important indicators of soil water budget (inasmuch as they influence vital factors such as the location of the capillary zone above the groundwater table). The reduction of the depth of fertile layer owing to permanently high or capriciously oscillating groundwater table (with repeated waterlogging) is hardly tolerated by any arable crop (PETRASOVITS, I. - BALOGH, I. 1975).

The transformation of the information of groundwater table maps into larger scales is aided by relief and drainage. In defining the categories of groundwater table the depths are regarded to which plant roots penetrate. The areas where groundwater levels sink below 5 m are labelled as 'areas with no groundwater', since few crops are able to receive moisture from such a great depth (even if the average 1 to 1.5 m capillary rise is considered).

The conditions of the above described factors fill the data base of the land suitability analyses.

Vegetation has not been mentioned among the environmental factors. The reason for this is that the target of the analysis is toward the land capability for the cultivation of arable crops and for each areal unit was assumed that the crop in question at the given stage is grown over the whole unit at a uniform level of agrotechnology.

7. COMPILATION OF SUITABILITY INDICATORS

In the Hungarian literature, Gábor GÉCZY gives the most concise formulation of arable land optimal for most of the crops (GÉCZY, G. 1968 p.26).

"Studying the requirements of plants against soils, it can be stated that a soil is advantageous for most of the commercial crops if it has

- neutral or slightly basic topsoil;
- stable crumb or slightly compact structure;
- CaCO in the topsoil but in a limited amount;
- a fertile layer at least 1 m deep and a humus horizon at least 50 cm deep and, finally,
- no salts harmful to the vegetation.

In areas with soils of the above properties, a great variety of crops can be grown successfully.)

He also refers to the differences between ecological demands. Cultivated crops differ in the degree to which they are capable to adjust to inimical environments, agricultural habitats of poorer quality. This statement is valid for both soil properties and other environmental factors.

The conditions of the physical factors which occur in Hungary are confronted with the ecological demands of crops through the suitability indicators as it has been described in the general presentation of the method. In the compilation of the indicators agricultural manuals, reports presenting the results of crop growing experiments and works on the geography of agriculture were applied.

A rank order of the relief, temperature, precipitation, and soil factors is established for each plant by their relative significance. Useful information is provided to this - among other sources - by the works of GÖRÖG, L. (1954), BACSÓ, N. (1963), VARGA-HASZONITS, Z. (1977), ERÖDI, B. - HORVÁTH, V. (1965) and the report entitled " The agroecological potential of Hungarian agriculture at the turn of the millennium (LÁNG, I. et al. - published in book form in 1983). According the order set up the mean temperatures or precipitation amounts of the critical months or - in the case of crops susceptible to soil quality - the genetic soil types are weighted four or twofold *(Tables 10-15)*. Among the suitability indicators of thermophile plants, mean temperatures for more than one month are included.

For some factors the yield-reducing conditions are only important, while for others the yield-increasing ones are by far of greater interest. In the first case, as for parent material, no 'excellent' conditions are indicated, the range ends with "favourable" conditions. In the second, however, there is no condition which excludes cultivation (as for water supply assuming irrigation) and therefore no 'unsuitable' condition is identified.

The (coded) conditions of the environmental factors are classified by land suitability for individual crops. Based on this classification, the programme of assessment prescribes the following 'scoring':

Table 1O Suitability indicators for wheat cultivation

Factor no	grades of suitability							
	+++	++	+	neutral	-	--	---	unsuitable /-12/
1.	1,2,4	3,5,6,8 1o	7,11,13 14	9,12,15-2o, 24,25	22,27,29	21,23,26 28,34,35 39	31-33, 36-38, 4o	41-148
2.	1o	9	8	5-7	4	2,3	1	none
3.	14	13	none	12,15	9-11	5-8	1-4	none
4.	14-16	13	12	11,17	8-1o	5-7	1-4	none
1o.	7,8	6,9	5,1o	4,11,12	3	2	1	none
13.	7,8	6,9	5,1o	4,11	3,12	2,13	1	none
17.	42,43,48 57,59, 61,64,67	4o,41 27,34, 39,56 6o,65 66	33,26,35 38,47,52 55,1o7	all other	18,19,28 71,81,83	17,21,22,	5,6,2o,68,7o 1o4,1o5	1-4,7-16,93-96, 1o1,1o3
18.	none	3-5,8-1o,13-15	none	all other	31,42,52, 112,117, 135,152	41,51,58 63,111, 116,147	22,56,57,61 62,81,82,91 92,1o1,1o2, 116,121,126, 127,141,146, 152	21,151
19.	3	4	2	6	5	none	1,7	none
2o.	3	2	4	none	none	1	none	5
21.	5	9,13	14,15 18	7,1o,16	6,11,17	none	1,8,12,19, 21,22	2-4,2o,23 24

Table 11 Suitability indicators for maize cultivation

Factor no	grades of suitability							
	+++	++	+	neutral	-	--	---	unsuitable /-12/
1.	1-4,6	5,7,8,10, 11,13	14,16,	all other	22,27,32, 39,40	21,23,26, 28,31,33, 37	36,38,44, 49,54,59	41-43,45-48,50-53, 55-58,60-148
4.	15-18	14	13	11,12	8-10	4-7	1-3	none
5.	16,17	14,15	13	11,12	9,10	6-8	1-5	none
6.	14,15	12,13	10,11	8,9	7	6	1-5	none
7.	16-18	15	13,14	11,12	8-10	4-7	1-3	none
8.	12-13	11	10	6-9	4,5	1-3	none	none
12.	10-12	8,9	6,7	3-5	1,2	none	none	none
14.	10-21	9	8	6,7	4,5	2,3	1	none
17.	34,42, 43,58, 59,63, 64	33,42, 57,62, 67,88	19,27,32, 35,41,52-54,56,60, 61,66,86, 87,89,90, 98,109,110	all other	17,30	6,29,83, 93,95	5,28,71, 82,84,94, 96,104, 105	1-4,7-16,68-70,72, 73,81,83,93,101-104
18.	none	3-5,8-10, 13-15	none	all other	47,52,82, 92,102, 147	46,51,81, 91,101, 117,146	22,116, 141,142	21,126,127,151, 152
19.	3	2,4	none	none	1,5	none	6,7	none
20.	3	2	none	none	none	none	1,4	5
21.	5,9	13	17	6,10,14, 18	1-3	7,11,15, 19	4,8,12, 16,20	21-24

Table 12 Suitability indicators for sunflower cultivation

Factor	grades of suitability							
	+++	++	+	neutral	-	--	---	unsuitable /-12/
1.	none	1,2,3,4, 5,6	7,8,lo,11, 13,14,16,17	all other	36,37,39,4o, 44,45,49,5o, 51,54,59,6o, 64,65,66,69, 75,79,8o,84, 89,94,loo	23,28,33, 38,41,46, 47,48,62, 74,9o,95 99	42,43,53,52, 56,57,58,63, 67,68,71,72, 76-78,81-83, 86,87,91-93, 96-98	73,88, lol-148
4.	15,16, 17	13,14	11,12	8-lo	7,6	4,5	1-3	none
5.	16,17	14,15	13	11,12	8-lo	5-7	1-4	none
6.	14,15	12,13	11	9, lo	7,8	5,6	1-4	none
7.	13,14	12,15	11,16	lo	9,17	8,18	5-7	1-4
15.	6-8	5,9	4,lo	11,12	3,13	2,14	1,15-17	none
17.	43,47, 48,54, 57-59, 62-64, 67	42,46,52, 53,39,35, 61,66	38,41,45, 51,55,6o, 65,9o,98, llo	all other	6,19,25,26 29,3o,32,35, 36,4o,44,49, lo8	5,18,24, 25,28,29, 31,78,8o 82,84,9o	17,24,28,77, 79,81,83,89, 94,96,lo2, lo4,lo7	1-4, 7-16, 68-73 93, 95,lol-lo3, lo6
18.	none	4,5,9, lo	3,8	all other	83,lo3,118, 132,143,148, 154,	82,lo2,117, 129,131,147, 153	81,lol,116 128,142,146, 152, 22	21,126,127, 141,151
19.	3	2,4	none	none	1	none	5	6,7
2o.	3	none	none	none	2	none	1,4	5
21.	9	5	17	14-16	2,6,7,lo,11 13	1,3,8, 18	4,12,19,	17,2o-24

Table 13 Suitability indicators for sugar-beet cultivation

Factor no	grades of suitability +++	++	+	neutral	-	--	---	unsuitable /-12/
1.	1,2,4,5	3,5,7,8	lo,13,16	11,14,17,19	9,12,15 2o	18,24,	29,32,39	21,23,25,28,3o,33, 35,38,4o-148
5.	15,16	14	13	11,12,17	7-lo	3-6	1,2	none
6.	11,12	lo,13	none	6-9,14,15	4,5	2,3	1	none
10.	11,12	9,lo	7,8	5,6	3,4	1,2	none	none
11.	14,15	11-13	9,lo	6,8	3-5	1,2	none	none
12.	none	12	11	6,lo	7,8	5,6	1-4	none
16.	7-9	5,6,lo	4,11	3,12,13	2,14-16	1,9,17 18	none	none
17.	58,59,63 64,67,98	34,57,62 66,43,97	33,41,42 56,61,62	all other	15,16,32 39,lo8	13,14,26 3o,38	12,25,29 31,35,37	24,28-3o,36 lol-lo5
18.	none	none	4,5,9,lo 14,15	all other	59,64,83 93,119,124 149	22,82,92 lo3,118, 123,148 154	21,58,63,81 91,lo2,117, 122,147,153	56,57,61,62,lol 116,121,146,152, 151
19.	3	2,4	none	none	none	none	1	5-7
2o.	3	none	none	none	none	none	2,4	1,5
21.	9	13	5	none	6-8,lo-12	17	1-4,6,7	18-24

Table 14 Suitability indicators for lucerne cultivation

Factor no	grades of suitability							
	+++	++	+	neutral	-	--	---	unsuitable /-12/
1.	2,4,6	1,3,5,8 1o,13,16	7,11,14,17, 19	9,12,15,18 2o,41-1oo, 1o6,1o8,118	1o1-1o5 1o7,1o9-117,119 12o	121-136	137-148	none
3.	15	14	13	11,12	9,1o	5-8	1-4	none
6.	none	12,13	none	8-11,14	6,7,15	1-5	none	none
7.	none	16,17	none	1o-15,18	6-9	1-5	none	none
14.	15-21	13,14	11,12	8-1o	5-7	3,4	1,2	none
17.	46-48 52-54 58-59 63,64 67	43,45,51 57,62,66	5,38,39,41, 42,5o,56,61 86,9o,98, 11o	all other	6,26,33 71,77,93 1o9	25,3o,32 8o,1o8	3,24,29,31 68,79,82	4,28,7o,69,72 73,81,83,84, 1o1-1o6
18.	2-5 15	1,1o,14	13	all other	58,62,84 94,1o4, 1o9,114 119,122, 134,136, 137,147	57,61,83, 93,1o3 1o8,113 118,121, 13o,133 143,154	56,82,92, 1o2,1o7,112, 117,129,131, 132,146,153	81,91,1o1,1o6 111,116,126-128 141,142,151,152
19.	3	2	none	4	1	5	none	6,7
2o.	3	none	none	none	none	none	2,4	1,5
21.	5,9	13,14	5,1o,11 15,18,19	6,7	1	2	3,8,12,16, 17,22-24.	4,2o,21,24

Table 15 Suitability indicators for viticulture

Factor no	grades of suitability							
	+++	++	+	neutral	-	--	---	unsuitable /-12/
1.	46,51,54 55,61,66 68,69,70 81,85,96 100	49,50,52,63, 64,65,67, 76,82,91,97, 109,112,121, 124,133,136, 145,148	21,26,31,36, 41,47,48,53, 56,62,105 110,122,129, 131,141,146	all other	23,28,33,38, 44,59,57,60, 63,72,71,87, 107,113,117, 119,131,143	42,44,48, 59,86, 101,114 125,137	43,53,58, 75,90, 102,126, 138	103,104 115,116, 127,128 139,140
4.	none	12-14	10,11,15	8,16,17,19	6,7	3-5	1,2	none
6.	none	9-13	14,15	6-8	4,5	3	1,2	none
7.	none	3-5	2,6	1,7-12	13,14	16	17,18	none
8.	11-13	10	9	7,8	5,6	3,4	1,2	none
9.	11,12	10	9	7,8	5,6	3,4	1,2	none
12.	none	1-3	4	4,6	7,8	9,10	11,12	none
14.	7,8	6,9,10	5,11	4,12	2,3,13	1,14	15-19	20-21
17.	none	none	none	all other	5	none	2,4	1,68-73,77-104
18.	5,10,15 20,140	25,30,35,40 45,49,50,55 70,75,150	80,85,90,95 100,105,110 139,145	all other	2,7,13,8, 18	23,28,33, 38,43,48 53,58,63 68,73,78, 83,88,93, 98,103,108 113,143, 142,148, 147	22,27,32, 37,42,47, 52,57,62, 67,72,77, 82,87,92, 97,102 107,112, 117-120 122-125	1,6,11,16,21, 26,31,36, 41, 46,51,56,61, 66,71,76,81, 86,91,96,101, 106,111,116, 121,126-136,141 146,151-156
19.	none	3	4	2	5	none	1	6,7
20.	none	none	none	1,2,3	none	none	none	4,5
21.	none	3,7,11,15, 19	2,6,10,14 18	4,8,12, 16,20	none	none	22,23,24	1,5,9,13, 17,21

suitability grade	scores
excellent	+ 3
very good	= 2
good	+ 1
medium	0
moderately restrictive	- 1
restrictive	- 2
very restrictive	- 3
unsuitable	-12

Summing up these scores, ecological rating is achieved. The presence of an 'unsuitable' condition does not mean automatical exclusion from the assessment but reduction by at least two ranks in the rating (so that the suitability in a given unit falls below medium).

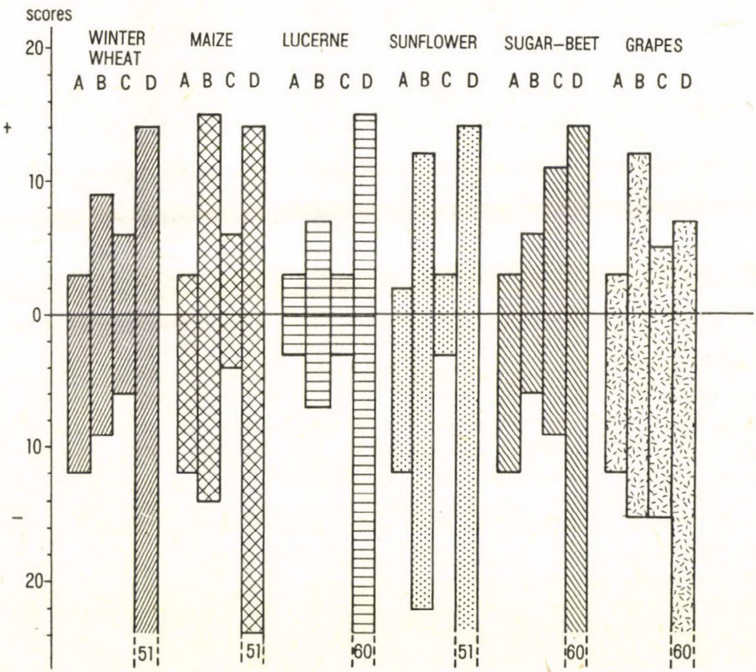

Fig. 6 Ranges of scores for the various crops.

A = relief; B = thermal conditions; C = precipitation; D = soils. The columns show the influence of the group of factors on land suitability in scores (+ = increased suitability; - = reduced suitability)

Figure 6 illustrates the range of influence of the various parameter groups on the value of the agricultural habitat by the crops studied. All these are naturally theoretical values, since when some parameters, such as monthly mean temperatures, are of average value regarding the ecological demands of a particular plant, this factor is neutral in the assessment, while other factors (water supply and soil properties) relatively increase in importance.

The ranges of scores vary with the diversity of the requirements of the particular crop and with its susceptibility to its environment.

At the next stage the programme of assessment attaches scores to the crops under study. Combining these preliminary scores, the final rank scores from 0 to 9 are established for each grid square and for each crop. *Figures 7-12* illustrate this by extracts from the grid maps. For some crops the differences are reduced by the statistical phenomenon of 'drawing to the average' and this can only be remedied through modifying the suitability indicators.

The final steps in the computer procedure are turning land suitability into a simple land capability through combining the individually printed grid maps of ecological suitability into an integrated map *(Fig. 13)*.

8. LAND CAPABILITY OF THE AGRICULTURAL AREA OF KOMÁROM COUNTY

Table 1 shows the contents of the data base built up of the coded conditions of factors for Komárom county.

The assessment involved six main crops (winter wheat, maize, sunflower, sugar-beet, lucerne, and grapes). These crops altogether make up 70 per cent of agricultural land in Hungary. Grapes were included to have an example of non-arable cultivation with significantly different ecological requirements.

As outlined above, upon the 23 topographic map sheets at 1:25,000 scale covering the 2443 sq. km area of the county (of which 2152 sq. km is agricultural land), a square grid of 4 sq. cm units was superimposed and the necessary information was coded from the resulting 25-ha squares. The assessment programme was run on Commodore-64 personal computer and the output was represented on the monitor screen by map sheets and crops. Subsequently, the maps of land suitability shown by rank scores were printed by C.ITOH 850 printer at approx. 1:45,000 scale, also by map sheets and individually for each of the 6 crops. To attain a visually better representation, the maps were combined into a single map of the county and coloured manually. (The latter became necessary since the colours on the photographs taken from the monitor screen were not clearly identifiable and the shape of squares was distorted.)

The final product, the land capability of the county based on suitability of six crops, is best visible on the colour maps. Here, however, only details of the black-and-white versions are reproduced, and, thus, some verbal explanation is indispensible *(Fig. 14)*.

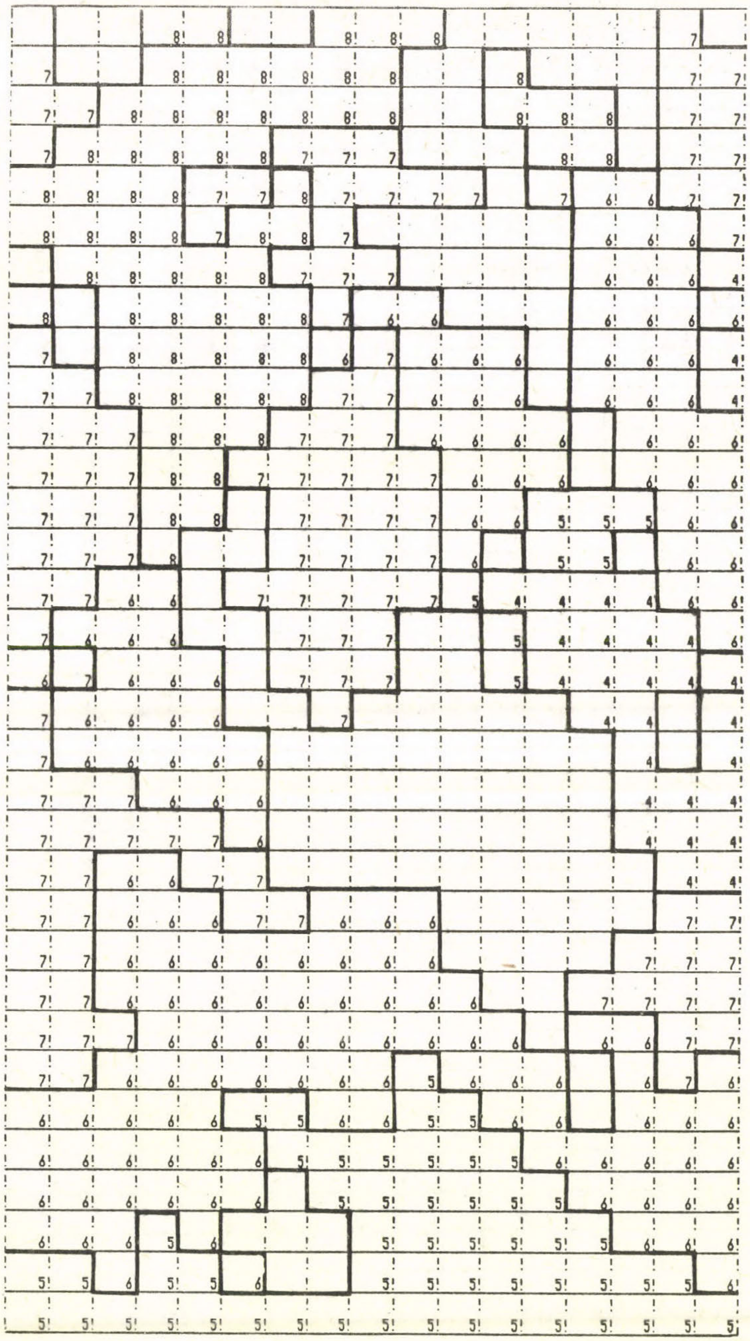

Fig. 7 Extract from the grid map showing the rank scores of land suitability for winter wheat cultivation.

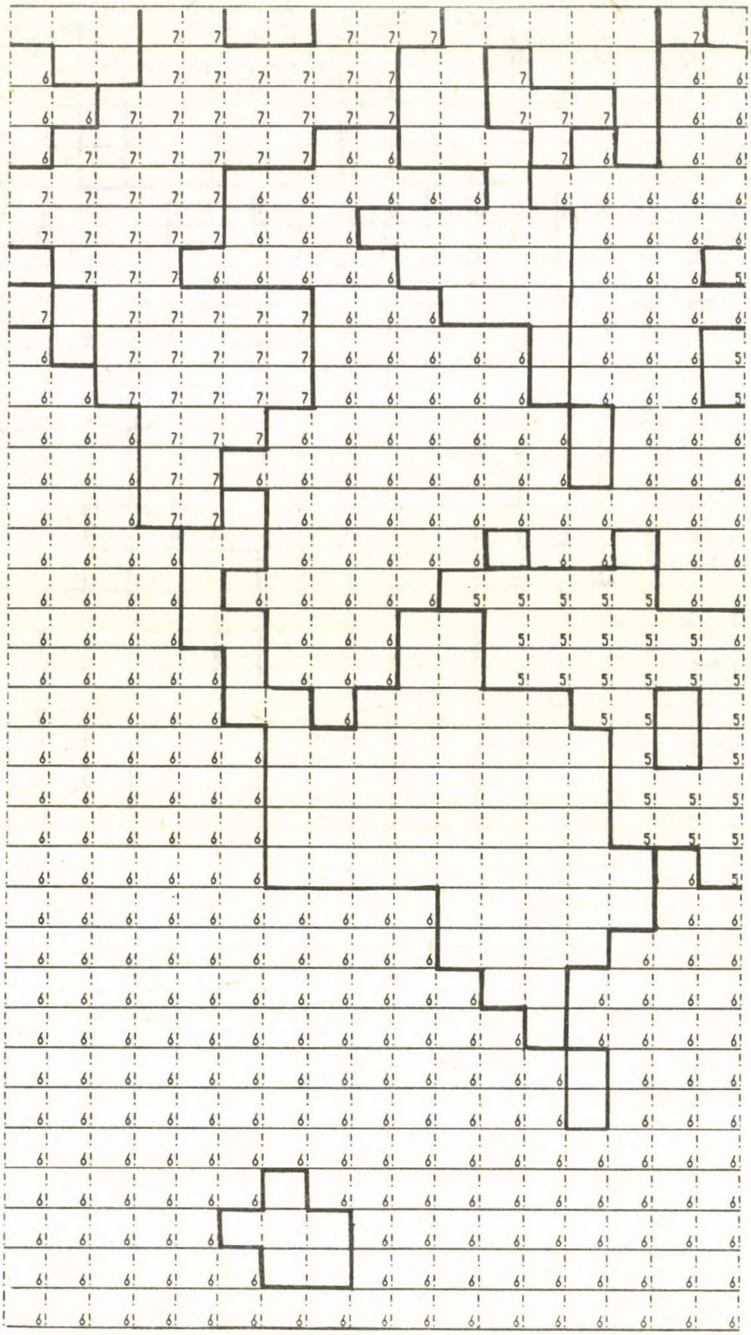

Fig. 8 Extract from the grid map showing the rank scores of land suitability for maize cultivation (the same area as in Fig. 7).

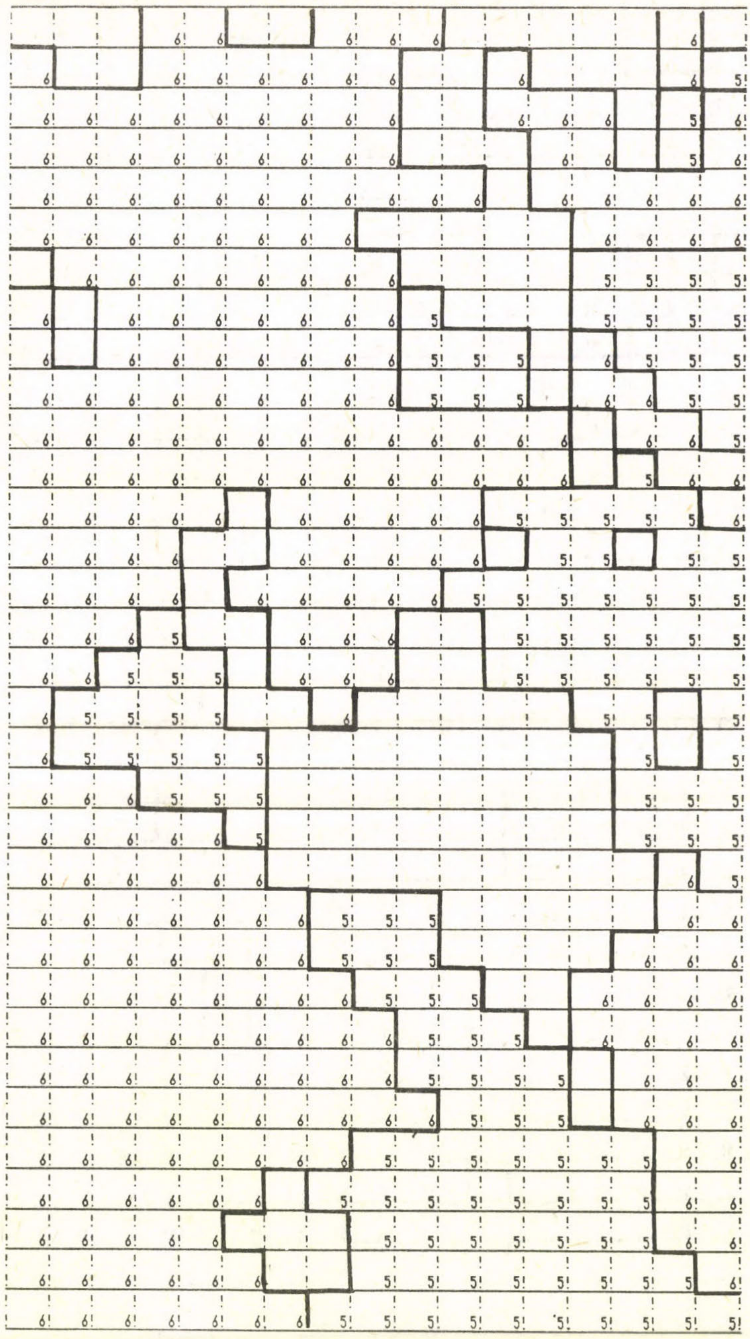

Fig. 9 Extract from the grid map showing the rank scores of land suitability for sunflower cultivation (the same area as in Fig. 7)

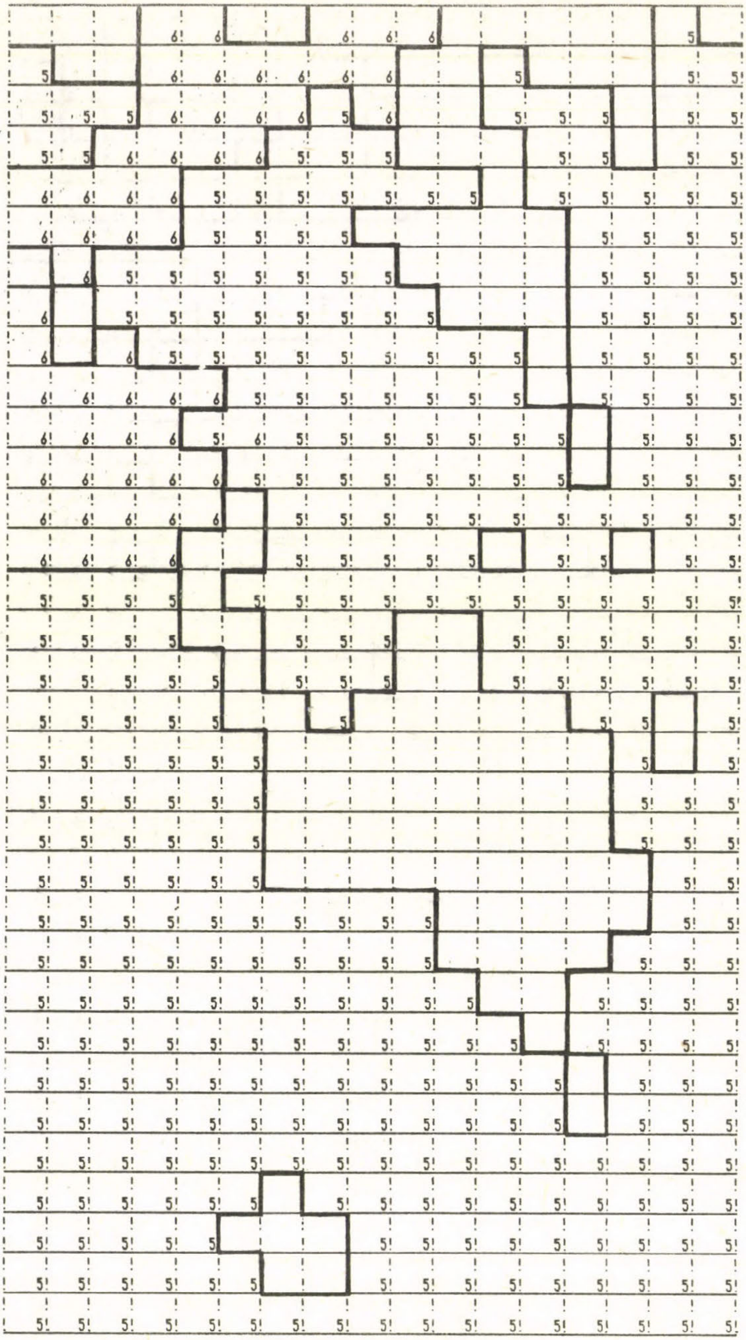

Fig. 10 Extract from the grid map showing the rank scores of land suitability for sugar-beet cultivation (the same area as in Fig.7).

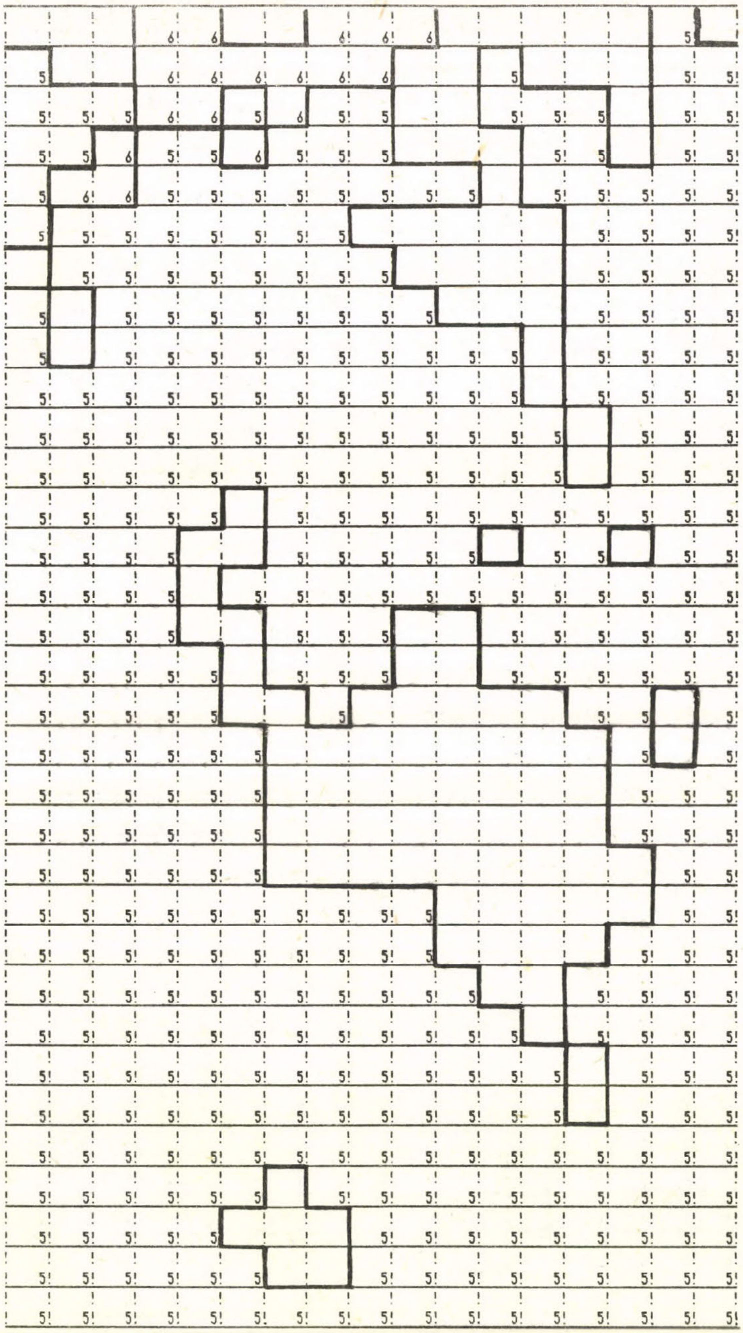

Fig. 11 Extract from the grid map showing the rank scores of land suitability for lucerne cultivation (the same area as in Fig. 7).

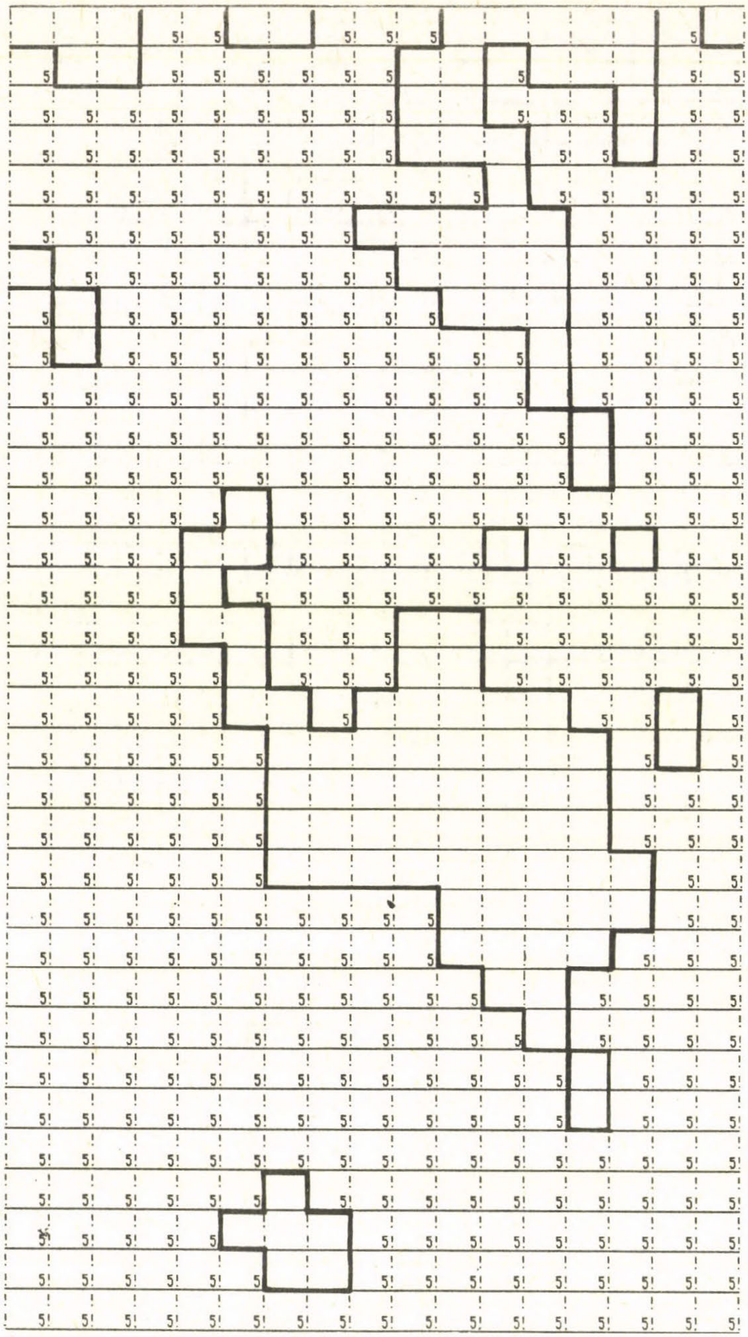

Fig. 12 Extract from the grid map showing the rank scores of land suitability for viticulture (the same area as in Fig. 7).

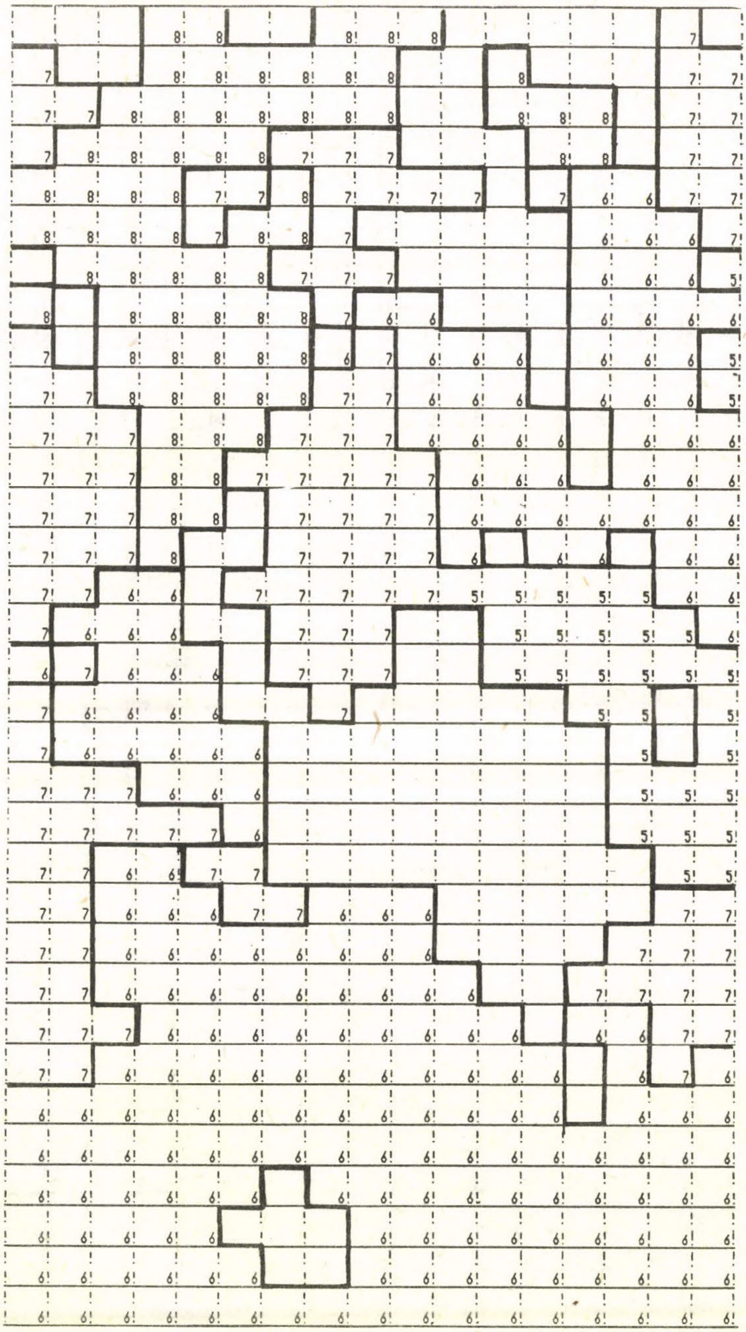

Fig. 13 Extract from the grid map showing maximum rank scores of the six crops (for the same area as above).

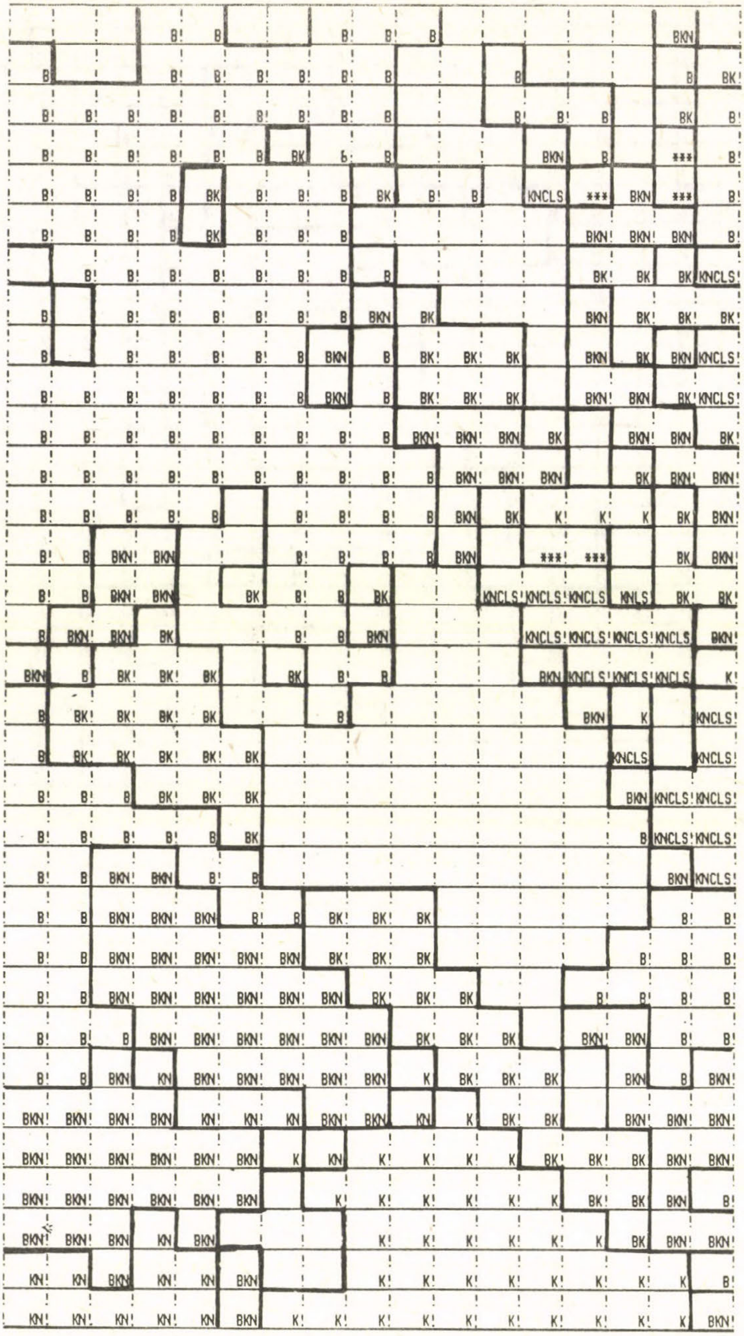

Fig. 14 Extract from grid map showing initials of crops with maximum suitability.
B = wheat; K = maize; N = sunflower; C = sugar-beet; L = lucerne; S = grapes; xxx = all the six

8.1. Land suitability for wheat growing

With regard to ecological suitability for wheat cultivation - even after three times repeated computer smoothing - the territory of the county shows a rather variable picture in some parts *(Fig. 15)*.

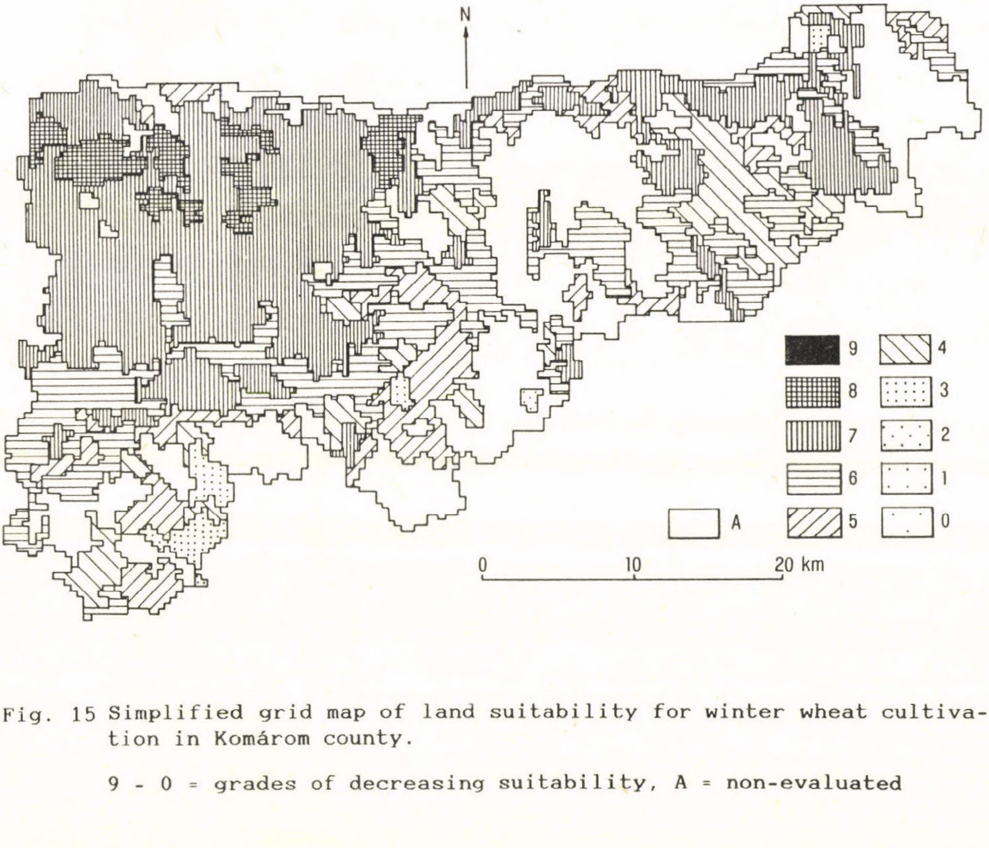

Fig. 15 Simplified grid map of land suitability for winter wheat cultivation in Komárom county.

9 - 0 = grades of decreasing suitability, A = non-evaluated

Suitability over the Tata-Komárom terraced plain stands out with its uniform excellent quality. Compared to the maximum possible value of 9, it has an average of 8 rank score and can be counted among the best wheat-growing regions of Hungary. To inform the farms about the quality of their land, a reduced scale version of the 1:100,000 scale field map of the county is attached *(Fig. 16)*.

A different situation is characteristic of land suitability for wheat-growing in the hill, basin (Dorog basin) and mountain-

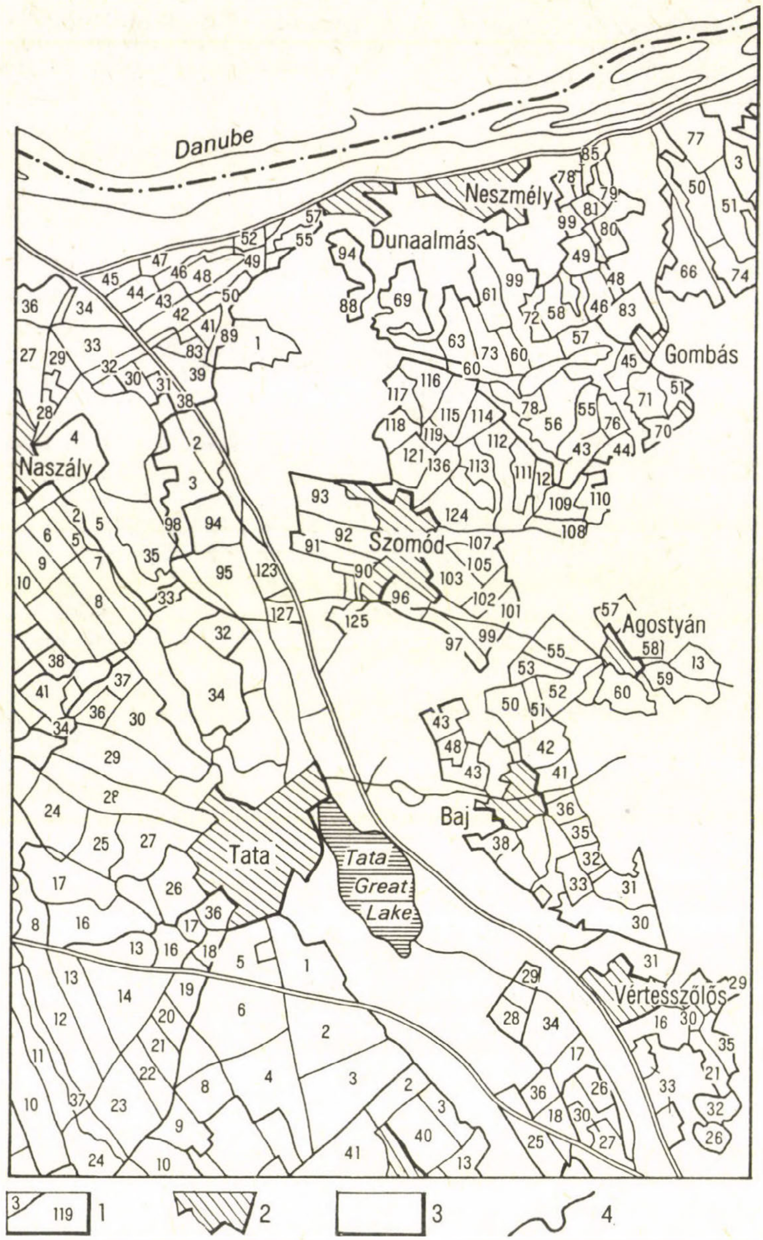

Fig. 16 Detail from the map of agricultural fields of Komárom county (compiled from farm maps).

1 = field with number; 2 = built-up area; 3 = non-agricultural area; 4 = farm boundary

ous parts of Komárom county. With deteriorating agroecological endowments of agricultural habitats, the rank scores of land suitability become of more scattered distribution, heterogeneous patches emerge with the prevalence of lower values for wheat growing.

The coded values in computer memory which form the background data base, enable us to find the reasons behind reduced or increased land quality in each of the 25 ha squares.

In general, the statement holds that most of the agricultural land of the county is excellent for wheat cultivation.

8.2. Land suitability for maize growing

Sharp contrasts are observed between the suitability of lowland and mountainous portions *(Fig. 17)*.

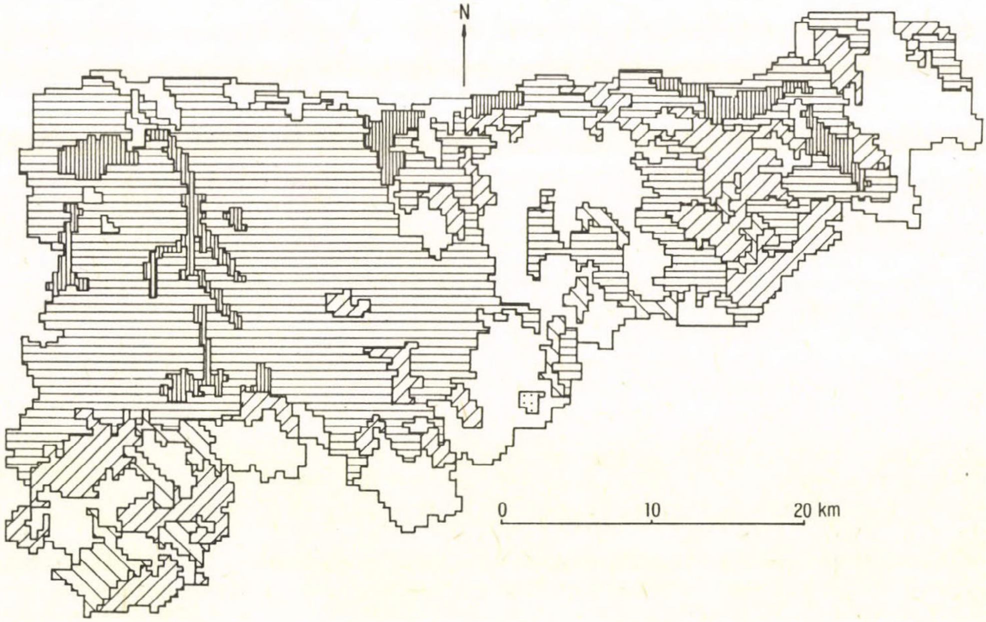

Fig. 17 Simplified grid map of land suitability for maize cultivation in Komárom county. For legend see Fig. 15

The land of favourable value (6) extends over the Tata Komérom terraced plain as far as the foothill areas. In two large spots the ecological endowments reach a higher degree of suitability (rank score 7). One of them lies in the vicinity of Bábolna a village renown for excellent yields (particularly due to advanced management and agrotechnique, rather than only to physical conditions), while the other is to the NNW of Tata. In addition, it is along water-courses that physical conditions are improved (rank score 7).

The less favourable tracts of agricultural land enclosed in the mountainous area have medium to higher medium values (4 to 5). "Islands" of better endowments occur in the Héreg-Tarján and Dorog basins and in the environs of Tatabánya.

In summary, most of the county area suits well for maize cultivation. Mosaical distribution is less manifest than in the case of wheat, since the excellent and the lower medium scores (8 and 3) are equally missing.

8.3. Land suitability for sunflower growing

The territory of the county is divided into two units by the contact zone of the lowland and the foothills *(Fig. 18)*.

A rank score of 6 is associated with the land suitability of the Tata-Komárom terraced plain and this means favourable conditions. This area is less extensive than that for maize growing as only includes the parts abundantly supplied with soil moisture from groundwater, and values indicating poorer environments (5) (restricted depth of soil fertile layer) appear on several places.

The mountains of the county have medium conditions (rank score 5) for sunflower cultivation. The Héreg-Tarján basin and the environs of Kesztölc only show higher values.

The occasional spots of poorer soils (values 4 and 7) make the picture mosaical, but these spots are of much lesser extension than for the two above crops.

Thus, most of the county's territory can be successfully utilized for sunflower cultivation.

8.4. Land suitability for sugar-beet growing

It predominantly falls in the medium class of rank score 5 *(Fig. 19)*. This area covers the mountainous parts of the county as well as the foothills and mountain forelands. The only exception is the favourable value (rank score 6) of the Dorog-Tokod semibasin results from more beneficial ecological conditions (water availability and protected mesoclimate).

Over the Tata-Komárom terraced plain the area of favourable cultivation potential is more restricted than for the above crops. With the adjacent land of the neighbouring Györ-Sopron county, this area supplies the sugar factory at Ács.

The reason for the sharp boundaries between areas of various values lies in the errors of processing which inevitably occur.

As a summary, it can be stated that in most of the county the ecological conditions are favourable for sugar-beet growing.

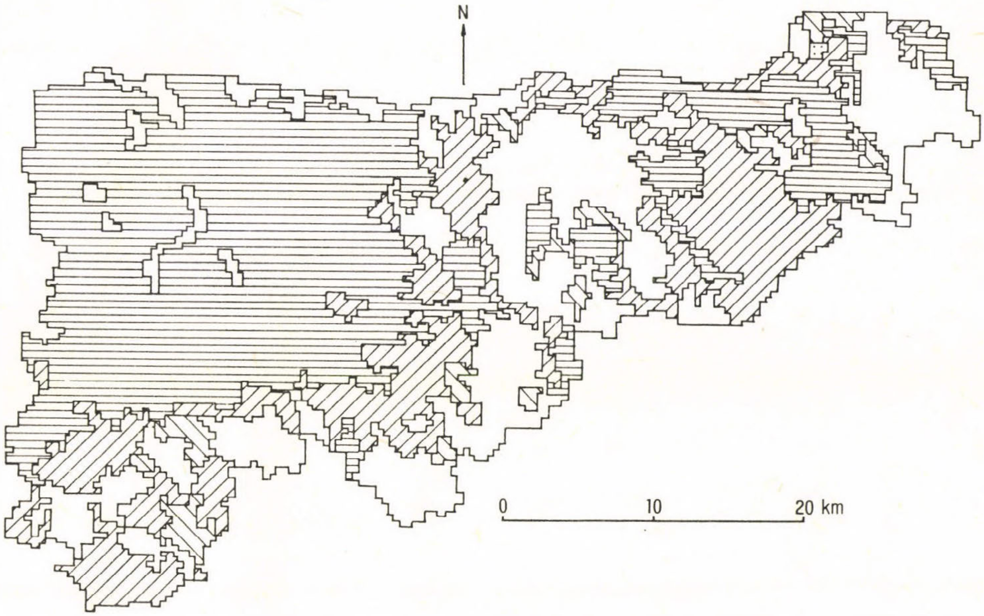

Fig. 18 Simplified grid map of land suitability for sunflower cultivation in Komárom county. For legend see Fig. 15

8.5. Land suitability for lucerne growing

The assessment map *(Fig. 20)* indicates preponderately medium ecological potential for most of the county's agricultural land.

For an expert of the agroecological conditions in the county this picture is not convincing. The need arises for the detailed supervision of the employed procedure of assessment, in its present form unable to grasp minor differences in suitability, since on the overwhelming majority of the agricultural land the depth of fertile layer is not restricted, soil parent material is fine-grained loose deposit of $CaCO_3$ and the genetic types of soils favour lucerne growing. Consequently, it seems likely that the ecological demands of lucerne should be inspected more profoundly.

Another possible way of a truer-to-reality assessment is through the more realistic weighting of suitability indicators.

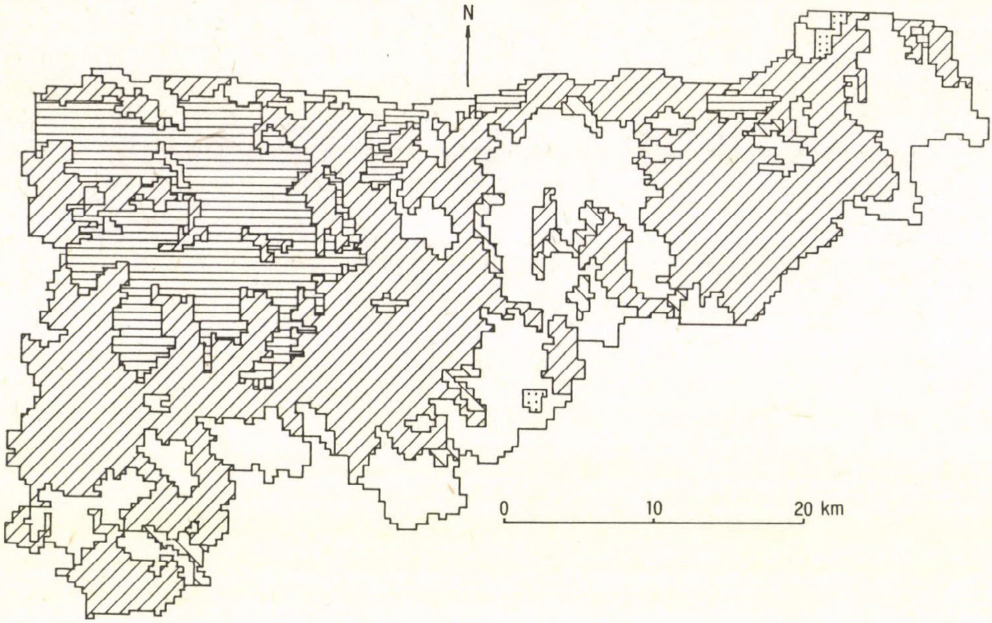

Fig. 19 Simplified grid map of land suitability for sugar-beet cultivation in Komárom county. For legend see Fig. 15

it will make the areally homogeneous map of medium values a mosaical one.

Both ways of correction require further cooperation from experts. This is being implemented now when we are extending our activity of assessment to the whole county.

8.6. Land suitability for viticulture

In an agricultural land predominantly used as arable like Komárom county ecological suitability for viticulture can have no higher than medium values as it is shown on the map *(Fig.21)*.

There is only a simple historical wine-producing region in the territory of the county, the Neszmély-Dunaalmás loess plateau and its south-exposed slopes.

It is striking still that the excellent endowments are not manifested in continuous spots and with high rank scores on the map. This fact obviously raises the problem of susceptibili-

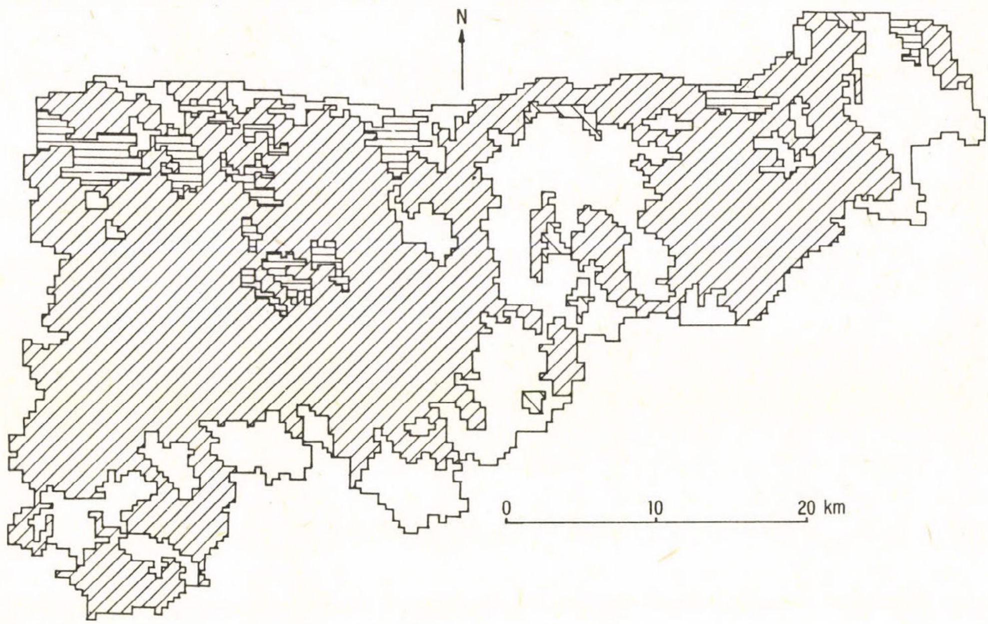

Fig. 20 Simplified grid map of land suitability for lucerne in Komárom county. For legend see Fig. 15

ty in relation to the indicators of ecological suitability.

In the interpretation of ecological demands in the history of the excellent wine-producing region a more profound analysis involving the special requirements of the major grape breeds is needed.

Nevertheless, in our opinion, the survey of land suitability for viticulture should not be restricted to the historical wine-producing areas, since viticulture is predominantly controlled by market conditions.

9. DELIMITATION OF AGROECOLOGICAL REGIONS IN KOMÁROM COUNTY

9.1. Regionalization efforts in Hungary

Various regional divisions in agriculture have been used in Hungary for half a century by official bodies and institutions in charge of analysing the relationship between agri-

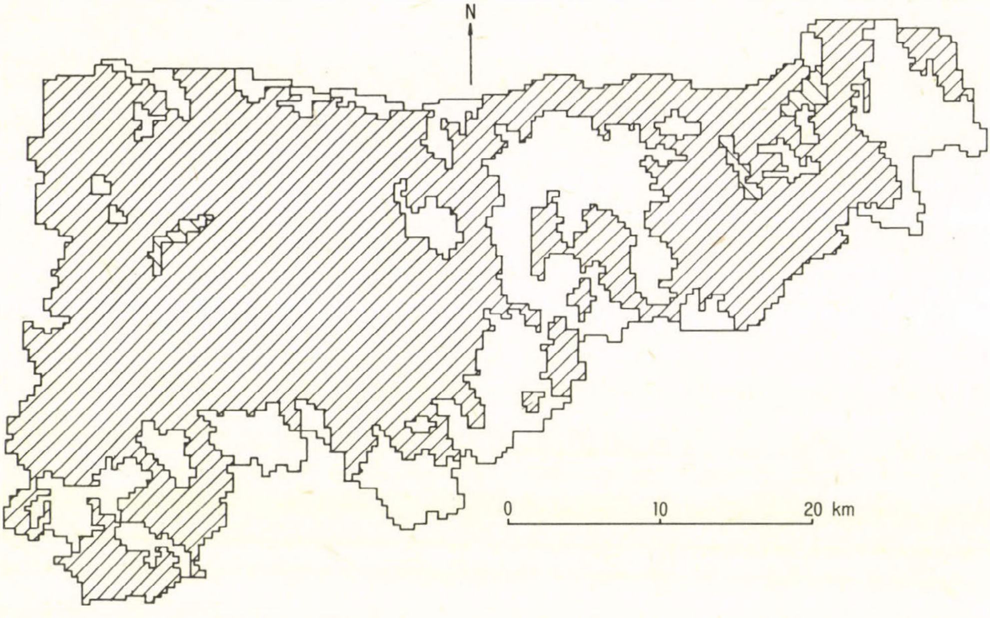

Fig. 21 Simplified grid map of land suitability for viticulture in Komárom county. For legend see Fig. 15

cultural yields and the conditions of production. Here only those are mentioned which include agroecological aspects. Reference should be made to L.KREYBIG's map (KREYBIG, L. 1946), which represents agriculture not only by the spatial distribution of the soil groups most influential - in his opinion - for cultivation, but also by the agroclimatic factors basically affecting the crop production.

Other works to be mentioned are L. GÖRÖG's 'Geography of agriculture in Hungary' (GÖRÖG, L. 1951) and I. SZÜCS' 'Map of agricultural regions' published in the series Területi Kutatások of the Geographical Research Institute, Hungarian Academy of Sciences (SZÜCS, I. 1980b).

In the introduction mention has been made of the map in the report 'The agroecological potential of Hungarian agriculture at the turn of the millennium', which shows 35 ecological (in fact, physical geographical) regions. They were further subdivided into area units ('regions') by overlaying an administrative map of the 19 counties and observing the two kinds of boundaries more than 200 'ecological regions' were identified. Output data, crop yields referring to them were collected for analysis.

Attention is best deserved by the regions of I. SZÜCS since they are founded on the assumption that - on the long-term - crop yields represent ecological endowments. Consequently, the map is constructed on the basis of the regional distribution of yields (and partly by physico-geographical regions). The assumption was logically correct, as - on the long-term - ecological potential attracts an appropriate supply of capital and, thus, in the evaluation the investments can be excluded from the *regional* differences of crop yields.

It is regrettable that the map relies on yields collected at a date when Hungarian agriculture intended to attain maximum crop yields without restrictions imposed on costs. Therefore, the map cannot be regarded the portrayal of agroecological regions.

9.2. Agroecological regions based on land suitability

Authors of the present book started from the following preconcept in the delimitation of agroecological regions: Having the maximum rank score in the 25-ha squares of the land suitability maps represented on a map (detail is shown in *Fig. 13)* and another map is constructed from the symbols of the crops with maximum suitability square by square *(Fig. 14)*, types of agricultural habitats can be identified and their spatial pattern automatically presents agroecological regions.

To this purpose, the locally rather heterogeneous pattern of suitability grades should be homogenized. This process was implemented through computer 'smoothing' which enhanced the dominant qualities and grouped the rank scores occupying inconsiderable spots together with their neighbourhood. This 'smoothing', repeated three times, proved to be efficient.

On the monitor screen patially distinct homogeneous spots of *various size* appeared and were printed. The areas indicated with the initial(s) of the crop(s) of maximum suitability and with rank scores of the corresponding degree of ecological suitability are regarded *types of agricultural habitat* (symbolized as B8, or KN 7,6 or BCNL 7,6,5 etc. - *Fig. 22)*. The Hungarian initials of the crops are the following: B for wheat, K for maize, N for sunflower, C for sugarbeet, L for lucerne and S for grapes. Under the letter figures indicate suitability grades for the particular crops.

These distinct types were delimited on the map and copied onto a transparency. On the transparency map of agricultural habitats such a regular pattern emerged that agroecological regions appeared striking to the eye.

The types of agricultural habitat manifest exact coincidence with relief in the area of lowland surfaces. In surfaces with heterogeneous and dissected relief the boundaries of the regions only loosely overlap with these of relief units.

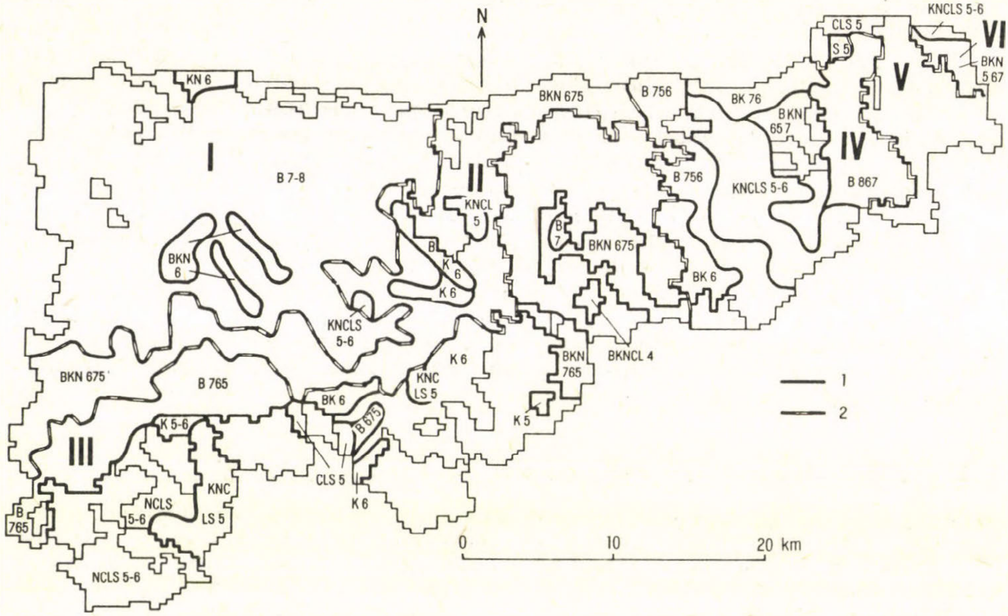

Fig. 22 Map of types of agricultural habitat and agroecological regions in Komárom county. Numbers indicate grades of suitability. For explanation of initials see Fig. 14.

1 = boundary of agricultural habitat types; 2 = boundary of agroecological regions

9.3. The regions of Komárom county

The method resulted in six agroecological regions for Komárom county. There are only two regions of their own right, the others are fragmentary ones stretching over to the area of the neighbouring counties *(Fig. 23)*.

Region 1 overlaps with the Tata-Komárom terraced plain (PÉCSI,M - SOMOGYI,S. 1980 - *Fig. 24*) and is characterized by excellent conditions for wheat growing. A homogeneous type of large extension (B8) is characteristic of the region.

Region 2 includes the northern foothill area of Transdanubian Mountains and the terraced valley of the Általér stream. It has higher-than-medium suitability grades for wheat, maize

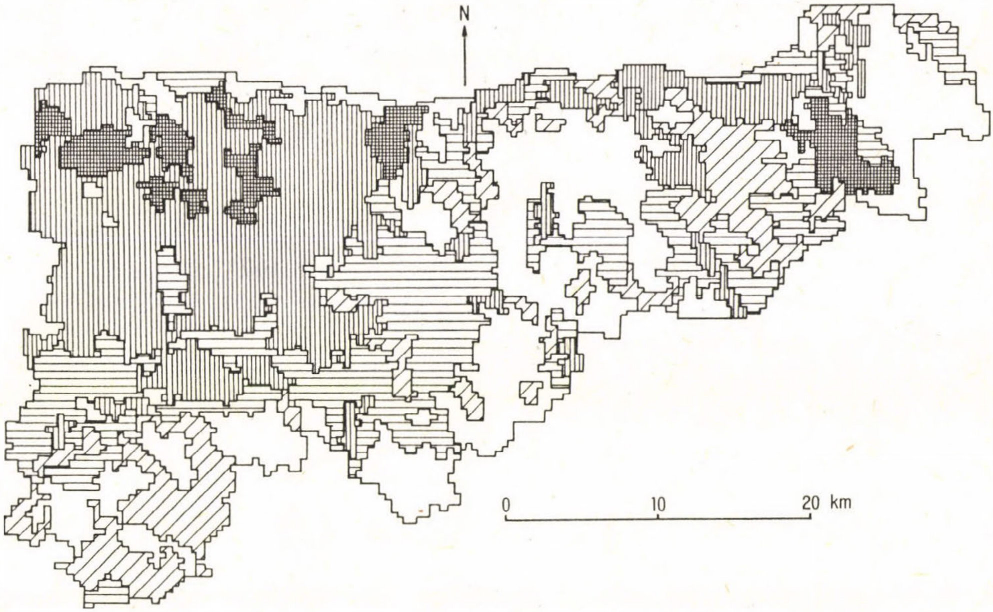

Fig. 23 Simplified grid map showing the maximum suitability scores by by units for Komárom county. For legend see Fig. 15

and sunflower growing and a mosaical pattern.

Region 3 covers the Dorog basin and its broader environs, but also has parts beyond the county boundary.

Region 4 is a mosaical region composed of three land capability types. Except for the narrow belt of the terraced plain, it is low mountains with basins. The Dorog basin is the centre along with the adjoining foothills of the East-Gerecse Mountains, is a good wheat and maize growing region and the southern part is of medium quality for sunflower cultivation. The Héreg-Tarján basin has the same endowments. The least favourable surfaces for cultivation are found in the higher parts of the East-Gerecse. Here rank scores are not higher than 6 for any of the main crops. The western slopes of the eastern Gerecse Mountains and the west-facing foothills of the Pilis-Visegrád Mountains are rather heterogeneous as regards land suitability, since the smaller were given rank scores of 7

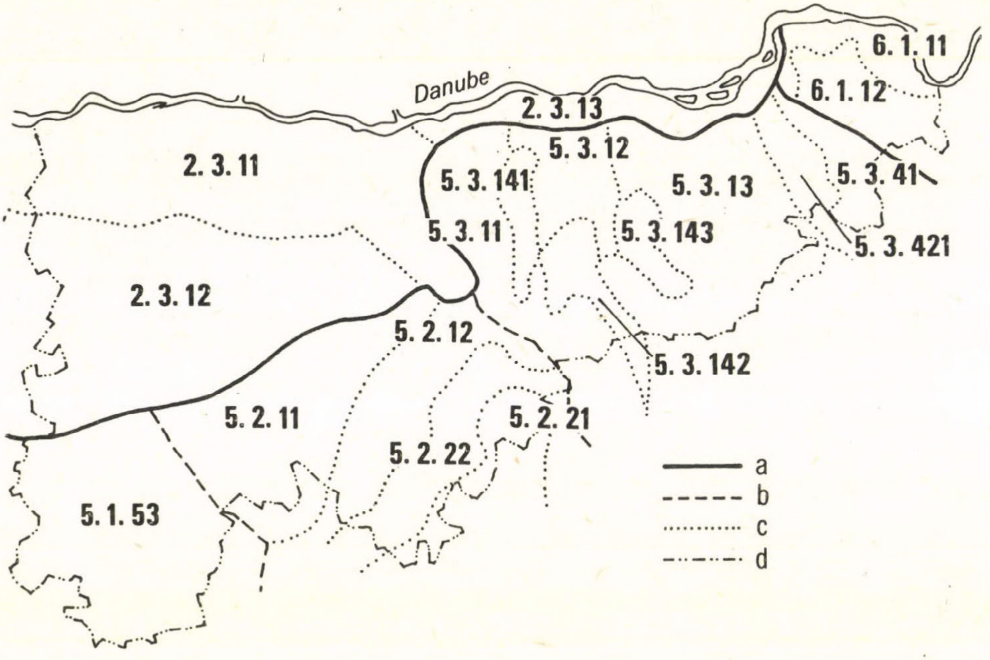

Fig. 24 Physical geographical divisions for the area of Komárom county (PÉCSI,M. - SOMOGYI,S. 1980)

2.3. = Komárom-Esztergom plain; 2.3.11 = Győr-Tata terraced plain; 2.3.12 = Igmánd-Kisbér basin; 2.3.13 = Danube valley; 5.1.53 = Bakony foothills; 5.2 = Vértes Mountains; 5.2.11 = Bársonyos hills; 5.2.12 = Általér valley; 5.2.21 = Vértes plateau; 5.2.22 = Vértes slopes; 5.3 = Danube Bend Mountains; 5.3.11 = W-Gerecse Mountains; 5.3.12 = Central-Gerecse Mountains; 5.3.13 = E-Gerecse Mountains; 5.3.141 = Tardos basin; 5.3.142 = Héreg-Tarján basin; 5.3.143 = Bajna basin; 5.3.41 = Pilis horst; 5.3.421 = Dorog basin; 6.1.11 = Danube Bend; 6.1.12 = Visegrád Mountains; a = boundary of macroregions; b = boundary of mesoregions; c = boundary of microregions; d = boundary of county

or 8 for wheat growing, while the slopes present values of 6 or 5. To the south, the region continues towards the Zsámbék basin.

Region 5 extends over most of the Pilis and Visegrád Mountains and manifests lower-than-average conditions for cultivation. Although the rank scores for viticulture are not reliable, in this region a small grape-growing area is distinct above Esztergom. To the east and south the region stretches over the boundary of Komárom county.

Region 6 coincides with the Pilismarót embayment and is strikingly different from its environs. It is a fragmentary region and has only a significant extension to the north, on the left bank of the Danube. It is a disconnected fragment of region 4, since on its northern margin endowments resemble to those on the higher terrains of the Eastern Gerecse Mountains, while the southern larger portion is identical in ecological value with the Dorog basin.

10. FINAL REMARK

Finally, as for any of similar regional divisions, the question of *reliability* has to be raised. We experimented with a comparison of the ecological suitability grades with crop yields in two of the county's farms. After proper areal correction correlation was calculated. The correlation coefficient for the Környe State Farm was sufficiently strong ($r = 0.78$), while the data only loosely correlated in the case of the Naszály Agricultural Cooperative ($r = 0.57$). No interpretation is attempted at here but it is to be noted that the relationship between yields and three factors of production (land, labour and capital) is well known. Yield itself, therefore, cannot be a measure of the reliability of an ecological potential survey.

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PART 2

A NEW COMPLEX PROCEDURE OF LAND EVALUATION

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1. INTRODUCTION

The new complex method for the evaluation of land, elaborated in the Geographical Research Institute of the Hungarian Academy of Sciences is based upon three indices:

1 - the numerical value of agricultural habitat, which expresses the ecological effect of the factors exerted upon the value of the agricultural habitat in points;

2 - the elasticity coefficient of agricultural habitat, which expresses the combined ecological and economic effect of the habitat factors upon the value of the productional site, in percentage of productional volume-elasticity;

3 - the basic price of fertile agricultural land, which is a function of returns of the elasticity coefficient and the actual interest rate.

2. ECOLOGICAL EVALUATION OF AGRICULTURAL HABITATS

The study of the previous relevant literature of Hungary and the socialist countries has led me to conclude that the new system of land evaluation can only be purposeful if it is implemented in a complex way, i.e. if a successful evaluation of agricultural habitats and on this basis, an appropriate land evaluation has been achieved, which would comprehend both the *ecological* and the *economic* evaluation of land. Namely, without an economic evaluation of land the points system of agricultural habitat evaluation would express only the relative quality of these habitats. Moreover, earlier attempts to an economic land evaluation were made without (or with some kind of) correction of the Goldkrone system. Consequently they were a priori wrong, and unacceptable.

As no novel, appropriate, complex land evaluation method had been found in the literature of agricultural economics, I set the aim to elaborate a procedure of complex land evaluation, in cooperation with an agrarian economist.

The most essential component of agricultural habitat evaluation, soil evaluation, was given (STEFANOVITS, P. et al, 1970). I have accepted it with minor corrections referring, first of all, to the evaluation of the parent material of soils.

For the evaluation of water conditions, the recommendations made in that study remained to be considered. However, going one step more, I have taken into account the most important water budget parameters of soils as well. This was necessary because they are not sufficiently reflected by the genetic soil system.

The evaluation of climate seemed not quite resolved by the approach done by N. BACSÓ and G. SZÁSZ (1977); it had to be revised and modified.

2.1. Evaluation of agricultural habitats by means of a points system

This system is based upon the relationship existing between the quality of the agricultural habitats and the yield of the plant cultivated there.

Subtracting the proportions of yield produced by the inputs of labour and capital from the multi-annual average yields, the portion of yield is obtained which is due to the quality of soil at the given technical level of production. This average yield proportion reflects correctly the fertility of the agricultural habitat.

If the proportion of multi-annual average yields due to soil quality can be extrapolated to the patches of agricultural habitats controlled by the most important ecological factors, the respective values for the fertility of the agricultural habitats of various quality can be assessed by points. An approximation of these values can be achieved by assessing the impact of soil, topography, climate and state of water supply upon fertility. These are called the value scores of agricultural habitats. They are assumed to express the real fertility of the habitats as influenced by physical environmental factors.

The highest quality habitat would be assigned 100 points while the worst one - 1 point only. In this manner, a sufficiently wide range of values are at our disposal to indicate quantitatively even minor differences in quality. Moreover, 10-point intervals are at hand for a ten-member subdivision.

When calculating the value scores of agricultural habitat at first the soils are given points. Subsequently, they are modified by subtracting correction values which express the negative effect of other ecological factors.

2.1.1. How to define the numerical value of soils ?

The present soil evaluation was elaborated by a research team (STEFANOVITS, P. et al, 1970). The values, expressed by points from 1 to 100, reflect the effective fertility of identical soil varieties represented by multi-annual average yields in agricultural habitats where no negative effect due to topography, water availability or climate could be proved.

The essence of the method is that a chart has been drafted, based upon the genetic classification of soils now used in Hungary. As the fundamental unit the *subtype* was adopted. To each of the subtypes, a base value of soil evaluation was assigned, indicating the lower and upper limits, for instance, the calcareous subtype of meadow chernozem ranges from 80 to 100 points.

Beside the base numerical values, partial numerical values indicate the various soil properties. The idea is that the greater the negative effect, the higher is the number of points assigned, which will be subtracted from the base value. The properties included are: parent rock, mechanical composition, thickness of humus layer, humus content, $CaCO_3$ conditions, depth of fertile layer and others. The reduced value will be the numerical soil value of the given subtype of soil.

For the determination of numerical soil values, along with the chart mentioned above, also a genetic soil map on scale 1:10,000 is needed, with attached chorograms illustrating the areal distribution of the properties to be taken into account and with the laboratory data.

The next step is to evaluate the effect of topography.

2.1.2. How to define the topographic correction value ?

According to the concept of the value score of agricultural habitats, the numerical value predominantly (between 75 and 90 % on the average) reflects the quality of the agricultural habitat. The residue is divided between the correction values concerning topography, water, and climate.

These have to be established relying upon objective investigations.

After STEFANOVITS, P. et al., in assessing the effect of the topography, first of all surface water loss is to be considered. Thus it seemed obvious to make use of the surface runoff, measured during a couple of years by means of rainfall simulation, in establishing the topographic correction value.

The runoff values measured on soil monoliths of undisturbed surface are reproduceable. In this way, they allow a reliable comparison of the runoff values of all soil varieties.

At present, in Hungary the number of the available data on rainfall simulation experiments is insufficient for compiling a table required to the evaluation of runoff. Therefore, each soil variety differing substantially in genesis and structure has to be rained, in order to establish the proper topographic correction value. The variation of potential water budget can be calculated. The necessary, at present missing, rainfall simulation experiments should be carried out aiming at the measurement and calculation of runoff for a country-wide land evaluation. Until this will be accomplished, the topographic correction values must be established separately for each particular case.

I simulated the various types of rainfall. The autumn upsliding rains were simulated by an artificial rain of 1 mm drop size and 1-5 mm/h intensity, the spring and early summer cyclonic rains by an artificial rain of 2 mm drop diameter and 1-15 mm/h intensity; the rainfalls of summer thunderstorm by an artificial rain of 3 mm drop diameter and 15-25 mm/h intensity. Raining was done at varying slope angles, by using a specially constructed device. The runoff values measured on the soil monolith of undisturbed surface at different precipitation intensities and slope angles were calculated by computer, within a chosen range, as a continuous function of slope angle and intensity of precipitation.

Thus it became possible to get an average value for each soil on the patches of each slope category, in the case of the three main types of precipitation.

Accordingly, the winter water loss was approximated by means of a runoff measured at an artificial rain of 3 mm drop diameter and 1-5 mm/h intensity.

To assess the effect of topography upon fertility, the soil loss due to water runoff should also have been taken into consideration. However, this had to be neglected, for several reasons. First of all because calculating the loss by using the equation proposed by WISCHMEIER, W.H. - SMITH, D.D. - UHLAND, R.E. (1958) one gets highly improbable values of negative correction. Furthermore, soil loss is only partially an ecological factor of the agricultural habitat being considerably controlled by agrotechniques.

Moreover, along with the slope angle, the length of slope also contributes to the effect of topography on water loss. The length of slope influences the actually observed portion of potential runoff, in function of surface ruggedness and the quantity of water accumulated. This effect of slope length has a bearing on soil erosion. An effect in this sense of slope length is expressed by the formula of WISCHMEIER, W.H. - SMITH, D.D. - UHLAND, R.E. (1958):

$$L = \left(\frac{f}{22.2}\right)^{0.5}$$

Therefore I decided to divide runoff range resulting at precipitation intensities of 1-5, 5-15, and 15-25 mm/h into 20 equal intervals (5 % each) and I made them correspond to 20 numerical values increasing by 0.25 % each. In this way, a coding table of runoff values was obtained *(Table 1)*. With its help, I constructed another table *(Table 2)*, which serves to establish the topographic correction values by slope categories and slope lengths, in a way that the runoff values are multiplied by the total of slope length correction values, and the average value is calculated for each type of precipitation. At a runoff induced by a shower, in the slope category of angles higher than 25 %, in the case of a slope longer than 150 m, the resulting value is decreased by a 20 % 'rill erosion value'. In this way, one obtains the topographic correction value which has to be subtracted from the numerical soil value.

The topographic correction value does *not* express the economic effect of topography exerted upon the value of habitat.

On a given patch of a slope category range the topographic correction value is calculated as follows:

Let us *a* represent runoff from a 1 mm drop diameter, 1-5 mm/h intensity artificial rain simulating autumn precipitation, *b* the value representing runoff from a 3 mm drop diameter, 1-5 mm/h intensity artificial rain simulating winter precipitation, *c* the value representing runoff from a 2 mm drop diameter 5-15 mm/h intensity artificial rain simulating spring precipitation, and *d* the value representing runoff from a 3 mm drop diameter, 15-25 mm/h intensity artificial rain simulating a summer shower.

The relative factors of slope lengths should range from 25 to 300 m e_1, $e_2, \ldots e_8$, respectively, the slope category ranges from 0-5 to 25-40 % I, II, III, IV and V, and the topographic correction value is *D*.

In this case, one possible combination of D_{III} would be

$$D_{III} = \frac{(a \cdot e_1)+(b \cdot e_1)+(c \cdot e_1)+(d \cdot e_1)}{n},$$

where n is a possible number expressing runoff intensity (1,2, 3, or 4 according to whether there is runoff at each precipitation intensity.) For instance, if a = 025, b = 075, c = 25, d = 4.75, then because e_1 = 1.061,

Table 1   Runoff correction table

Runoff per cent	Average runoff (mm per h) from simulated rainfall of 5 mm/h intensity	10 mm/h	20 mm/h	Runoff correction value
0 - 5	0.25	0.5	1	0
5 - 10	0.50	1.0	2	0.25
10 - 15	0.75	1.5	3	0.50
15 - 20	1.0	2.0	4	0.75
20 - 25	1.25	2.5	5	1.0
25 - 30	1.50	3.0	6	1.25
30 - 35	1.75	3.5	7	1.50
35 - 40	2.0	4.0	8	1.75
40 - 45	2.25	4.5	9	2.0
45 - 50	2.50	5.0	10	2.25
50 - 55	2.75	5.5	11	2.50
55 - 60	3.0	6.0	12	2.75
60 - 65	3.25	6.5	13	3.0
65 - 70	3.50	7.0	14	3.25
70 - 75	3.75	7.5	15	3.50
75 - 80	4.0	8.0	16	3.75
80 - 85	4.25	8.5	17	4.0
85 - 90	4.50	9.0	18	4.25
90 - 95	4.75	9.5	19	4.5
95 -100	5.0	10.0	20	4.75

The relative coefficients of slope length are

25 m = 1.061	150 m = 2.599
50 m = 1.5	200 m = 3.001
75 m = 1.838	250 m = 3.556
100 m = 2.123	300 m = 3.676

D_{III} (with a slope category of 12-17 %)

$$= \frac{(0.25\cdot 1.061)+(0.75\cdot 1.061)+(2.5\cdot 1.061)+(4.75\cdot 1.061)}{4} = 2.3$$

Obviously a great many combinations are possible, because the slopes in the same category are rarely of the same length. In such cases a weighted average slope length should be calculated

If on the map a slope category is cut into two by a soil boundary, the topographic correction values should be established separately for the two slope category patches, because the runoff values of the two soils are different.

The calculated topographic correction value is subtracted from the numerical soil value.

Table 2 Example of table of correction values for soils

Slope length, m	Slope length correction value	Slope category, per cent	Product of runoff value for seasonal (autumn, winter, spring and summer) rainfall types and slope length value				Topographic correction value
			Intensity, mm per hour:				
			1-5	1-5	5-15	15-25	
			Drop diameter, mm:				
			1	3	2	3	
25	1.061	0 - 5					
50	1.5	0 - 5					
75	1.838	0 - 5					
100	2.123	0 - 5					
150	2.599	0 - 5					
200	3.001	0 - 5					
250	3.556	0 - 5					
300	3.676	0 - 5					
25	1.061	5 -12					
50	1.5	5 -12					
75	1.838	5 -12					
100	2.123	5 -12					
150	2.599	5 -12					
200	3.001	5 -12					
250	3.556	5 -12					
300	3.676	5 -12					
25	1.061	12-17					
50	1.5	12-17					
75	1.838	12-17					
100	2.123	12-17					
150	2.599	12-17					
200	3.001	12-17					
250	3.556	12-17					
300	3.676	12-17					
25	1.061	17-25					
50	1.5	17-25					
75	1.838	17-25					
100	2.123	17-25					
150	2.599	17-25					
200	3.001	17-25					
250	3.556	17-25					
300	3.676	17-25					
25	1.061	25-40					+20%
50	1.5	25-40					+20%
75	1.838	25-40					+20%
100	2.123	25-40					+20%
150	2.599	25-40					+20%
200	3.001	25-40					+20%
300	3.676	25-40					+20%

Indispensable prerequisites for determining the topographic correction value are the availability of slope category and genetical soil maps for the area concerned.

2.1.3. How to define the correction value of water utilization ?

Water is just as important an ecological factor of habitat quality as the soil itself; both are equally essential conditions of crop yields. The effect of water need not be evaluated on flat surfaces or low angle slopes only.

The appraisal of the measure to which the plants utilize the water infiltrated into the soil cannot be avoided or neglected. This is indispensable to assess in a realistic manner at the given agricultural habitat. Now, water utilization cannot be deduced from the genetic properties of soil; measurements are needed. They are to be made at the habitat just like soil mapping. Neither of them can be omitted for financial reasons.

Applying the hydrological functions deduced from data obtained from rainfall simulation (GÓCZÁN, L. and SZÁSZ, F. 1969, 1970), the amount of water infiltrated into the soil was computed as a function of rainfall intensity in the 0-40 mm/h range and of slope angle in the range of 0-40 per cent.

The next step was to calculate permeability for the individual patches of slope categories, using the same rainfall intensities and slope inclinations as in the case of the topographic correction value.

Water permeability measured for 5, 10 and 20 mm/h rainfall intensities was divided into 5 per cent intervals. The measured and calculated values were high, so they would have produced an exaggerated decrease of the numerical soil value. For this consideration, a series of figures decreasing from 4.75 to 0 by 0.25 intervals were rendered to them. (This is an inverse series of figures if compared to the correction values representing runoff when determining the topographic correction values.) The resulting auxiliary table codes the measured and calculated values for water permeability *(Table 3)*.

The correction value representing permeability is not multiplied by the relative coefficient of slope length, because in this case the length of the slope does not interfere. On the contrary, the available water capacity of 1 m section of the studied soil is taken into account.

This requires, however, the determination of the available capacity of a 1 m thick layer of every soil variety with essentially different water budgets. This must not be hampered by the costs involved either. To determine the available water capacity is an important and valuable work even independently of agricultural habitat evaluation.

The values of available water capacity are too high figures for direct use in the developed system of numerical soil values. Therefore, the thousandfold of reciprocal value of the measured available water capacity as a figure to be added to the value representing water permeability proved to be appropriate.

Table 3 Auxiliary table to establish the values for the amount of water infiltrated into the soil

Permeability, per cent	Average permeability for simulated rainfalls of 5 mm per hour intensity	10	20	Correction value of permeability
0 - 5	0.25	0.5	1.0	4.75
5 - 10	0.5	1.0	2.0	4.5
10 - 15	0.75	1.5	3.0	4.25
15 - 20	1.0	2.0	4.0	4.0
20 - 25	1.25	2.5	5.0	3.75
25 - 30	1.5	3.0	6.0	3.5
30 - 35	1.75	3.5	7.0	3.25
35 - 40	2.0	4.0	8.0	3.0
40 - 45	2.25	4.5	9.0	2.75
45 - 50	2.5	5.0	10.0	2.5
50 - 55	2.75	5.5	11.0	2.25
55 - 60	3.0	6.0	12.0	2.0
60 - 65	3.25	6.5	13.0	1.75
65 - 70	3.5	7.0	14.0	1.5
70 - 75	3.75	7.5	15.0	1.25
75 - 80	4.0	8.0	16.0	1.0
80 - 85	4.25	8.5	17.0	0.75
85 - 90	4.5	9.0	18.0	0.5
90 - 95	4.75	9.5	19.0	0.25
95 -100	5.0	10.0	20.0	0

In possession of these two figures I compiled another auxiliary table *(Table 4)* to facilitate the determination of the numerical correction value of water utilization.

Table 4 Auxiliary table to establish correction value for water utilization

Slope category, per cent	1000 times the reciprocal value of available water capacity	Permeability value at rainfalls of 1-5 mm per hour intensities aut.	1-5 wint.	5-15 spr.	15-25 sum.	Correction value of water utilization

In case of clay content over 40 % V + 20 % lack of air
In case of water covering less than 2 weeks V + 25 %
In case of water covering more than 2 weeks V + 50 %
In area of groundwater effect inducing meadow soil dynamics V + 75 %
In area of groundwater effect inducing bog soil dynamics V + 100 %
In case of clay content higher than 40 % V + 20 %

The numerical correction values of water utilization thus obtained are subtracted from the numerical soil values calculated for each patch of slope category.

In order to show an example of establishing the numerical correction value of water utilization, let the numerical values representing permeability at various rainfall intensities in cases 1-4 be f, g, h and i; (1000/DVcap) = j; the slope categories successively I, II, III and IV; the numerical correction value of water utilization V;

$$V_I = \frac{f + g + h + i}{n} = j$$

where n is the sum of occurrences of the figure representing water permeability (it may be 1, 2, 3 or 4). In a concrete example:

$$V_{IV} = \frac{0.25 + 0.75 + 1.5 + 3}{4} + 4 = 5.4$$

2.1.4. The climatic correction value

The five districts identified on the map of BACSÓ, N. and SZÁSZ, G. (1977) are represented in the present system of agricultural habitat evaluation by the successive correction values of 0, 1, 2, 3 and 4, simply because higher correction values would produce an unacceptably exaggerated outcome.

Another climatic correction value is associated with wind damage on slopes with angles above 25 per cent and on relatively elevated ranges narrower than 50 m as well as in areas of wind frequency.

The value of the agricultural habitat is diminished by the föhn effect in rain shadow on long, abrupt slopes of sudden exposure in medium-height mountains. The patches of frost and fog traps must also be considered.

Last but not least, slope exposure is also counted among the climatic effects, because of the differences in insolation, in the case of slope angles above 25 per cent and slope length more than 50 m.

Climatic correction figures, in addition to the district base values, are

Wind damage	2 points
Effective föhn effect	2 points
Frost trap	5 points
Fog trap	2 points

Exposure (if slope angle exceeds 25 per cent, slope length above 50 m):

N, NE	3 points
E, W, NW	2 points
S, SE, SW	1 point

Now the figure of the ecological habitat value is obtained by adding up the topographic, water utilization and climatic correction values and by subtracting the total from the formally determined numerical soil value.

Logically considered, the double - ecological and economic - effect of the habitat factors cannot be expressed by a single numerical value. Some other way had to be sought to resolve this problem.

The ecological numerical value of agricultural habitat represents its fertility at a given productional-technical level It is relatively constant as explained by authors, who elaborated the system of numerical evaluation of soils.

The other value should be an elastic number which includes the first - since it is interconnected with its content - and which also expresses the economic effect of habitat factors. Under the conditions of socialist economy this number does not include the effect of the distance from the market because this is not a complex potentiality (habitat quality and economic value), but from the viewpoint of the value of the agricultural habitat it is only a simple, economic income-controlling factor. Under socialist economy (as argued by several agricultural economists), this is not to be included in the value of land, since purchase prices do not depend on distance of transportation and a complex land evaluation can only be based on the crop production value instead of net income.

This second numerical value should be elastic since the economic effect of habitat factors on the value of the agricultural habitat changes relatively rapidly (and ever faster) parallel with the development of agricultural technics, and this numerical value should follow this change easily and sensitively. Thus, applying this value, there is an opportunity of calculating the price of land under socialist conditions.

To compute the value of elasticity for the agricultural habitat, the differentiated measure on the gross crop production value should also be investigated in relation to labour and capital investments.

This problem was believed to solve by the modified variety of the production function of COBB-DOUGLAS as applied by Iván BENEŢ, an agricultural economist of the Research Institute for Economics of the Hungarian Academy of Sciences.

The function was used in the form below:

$$Y = a\ S^{\alpha}\ L^{\beta}\ C^{\gamma}$$

where Y = the result variable, here is the gross crop production value,

a = the factor of efficiency,

α, β, γ = coefficients of elasticity,

S = the index of the value of the agricultural habitat weighted by the area, in terms of points,

L = labour input in forints,

C = capital/materialized labour/input in forints,

$\alpha + \beta + \gamma \approx 1$ = coefficients of volume elasticity.

In the farm which is to be chosen for land evaluation, the evaluation of the agricultural habitat should be carried out by plots of farm. The quantification of input can be solved only projecting to the least areal farm units. In favour of the identity of areal units according to the requirements when investigating the relationship between the three productional factors and production value the point values of habitats within the plots should be written in the matrix by weighting according to their areal extensions.

The task is to project the gross crop production value, Y, step by step to plots, then the projection of the direct and indirect labour inputs to each plot. To describe the latter in more detail; this is the quantification of the input of fixed assets, i.e. of the direct and indirect tractor, lorry and machine input, the costs of keeping draught animals on the basis of the employment, further the quantification of the use of fertilizers and pesticides representing the current assets.

In favour of the reliability of the result the relationship between the production factors and output was tried to express by other computer solutions differing from those above. For instance, gross production value was replaced by gross income, in another case by net income, then by GE. In another variety the numerical values of agricultural habitat were replaced by the numerical values of soil and by the Goldkrone values, as well. Finally, the capital inputs were divided into several components. The plots of high standard deviation, i.e. of extremely high Y-values surrounding plot average were omitted from the matrix.

The solution of the logically expected variation, i.e. the formula containing the probability variables of the original function only proved to be successful when the extreme high Y-values were omitted.

The computation of powers of the function produces the proportion rate of the three production sources responsible for gross crop production value.

In this way the value of elasticity for the agricultural habitat, i.e. α averaged to the area of the farm in question, is obtained. Further two elasticity coefficients, the β and γ, characteristic of farm management, will also be defined. They categorize crop production yield also according to labour and capital. The last two coefficients are not included in the land evaluation method. These are to be computed only in favour of computability of the coefficient of elasticity for the agricultural habitat.

The numerical value of elasticity for the agricultural habitat expresses the ecological and economic habitat effect integrated on farm level. If available for the areas of the farms with relatively similar quality of habitats and use, the numerical value of elasticity for the agricultural habitat averaged to the soil subtypes can also be obtained. Thus, there is a theoretical opportunity to cut the coefficients of elasticity for the agricultural habitat from the administrative areas of the farms. The other possibility seems to be more feasible; instead of the obsolete estimation and classification districts, and on the basis of the coefficients of elasticity for the agricultural habitat and of its ecological numerical values, the land evaluation units of similar habitat conditions (similar averages of coefficients of elasticity) of the same function should be indicated, or the correctness of delimitation should be checked with their help.

2.2. A possible calculation of the price of land under socialism

The basic price of land depends on three factors:
- on the magnitude of the crop production proceeds obtained in unit area,
- on the coefficient of elasticity for the agricultural habitat,
- on the valid rate of interest,

according to the formula below:

$$\text{basic price of land} = \frac{Y}{T} \cdot \alpha \cdot \frac{1}{k},$$

where T = agricultural area in (thousand) hectares,
Y = the crop production proceeds in forints in the areas in question,
k = rate of interest.

The price of land may vary on a wide range within the farms. By means of the formula above the price of land can be determined for each plot.

If the projected use of land is not agricultural, the price of this abandoned tract is calculated through multiplication by β (representing capital investments) as well as by α. The resulting figure is the *expropriation price of land.*

Expressed in formula:

$$\text{KFá} = \frac{Y}{T} / \alpha + \beta / \frac{1}{k},$$

where KFá is expropriation price and other parameters are the same as in the previous formula.

2.2.1. The ecological value of agricultural habitat expressed in money terms

When dividing the price of land of the unit areas calculated to each plot by average numerical value of the agricultural habitat within the plot, the 'unit price' of the average numerical value of agricultural habitat will be obtained for the given plot. The money equivalent of one average point can be calculated in the same manner from the average numerical value of agricultural habitat for the whole farm.

ATTEMPT AT LAND EVALUATION IN A LOWLAND AND IN A HILL AGRICULTURAL REGION

To collect practical experience about our land evaluation method, a survey was carried out in the "Búzakalász" Cooperative of the village Mocsa, Komárom County *(Fig. 1)*, and in the "Béke" Cooperative of the village Udvari, Tolna County *(Fig. 2)*.

In the two farms the conditions for land evaluation were created by ourselves since the practical test of the method required the control of each step in order to eliminate errors.

Having established the morphological, water utilization and - if it was necessary - the climatic correction numbers, the agricultural habitats were mapped and evaluated for both farms, also by plots. The correction factors necessary for the evaluation of agricultural habitats were arranged in a table marking the habitats for easy performance of areal weighting for computing the averages of plots.

The averaging of habitats was carried out also according to the areal spots of soil sub-types within the plot, together with areal weighting. This highly promoted applicability.

As a result, averaged to farm plots and weighted by areas the data series of F_1 (numerical value of soil averaged and weighted by plots) and of F_2 (numerical value of agricultural habitat obtained in the same manner) were acquired for the table of the land evaluation data base.

This was followed by the quantification of the proceeds, labour and capital in forints.

To perform this work, the field registry and bills of the two farms were used. The only problem was that whether multiannual averages or the data representing the best average should be used. The latter possibility was chosen with particular arguments (BENET, I. - GÓCZÁN, L. 1973).

In case of the land of Mocsa the form of the function is:

$$Y_1 = F_2^{\alpha} L^{\beta} K_2^{\gamma},$$

where Y_1 = gross crop production value,
F_2 = numerical value of agricultural habitat times extension of the area in (thousand) hectares,
L = direct and indirect labour in forint,
K_2 = direct and indirect capital plus fertilizer utilization in forints.

The solution is:

$$Y_1 = 16.43 F_2^{0.29} L^{0.13} K_2^{0.56}$$

$\alpha+\beta+\gamma = 0.98 \approx 1.00$
$S_y = 5911.3$
$H_r = 0.017$
$R = 0.899$

In case of the land of Udvari the function differs from that of Mocsa by K_3. Here K_3 is direct and indirect capital investment plus fertilizer utilization plus pesticide utilization.

Accordingly, the solution of the functions:

$$Y_1 = 6.86 F_2^{0.19} L^{0.44} K_3^{0.41}$$

$\alpha+\beta+\gamma = 1.04$

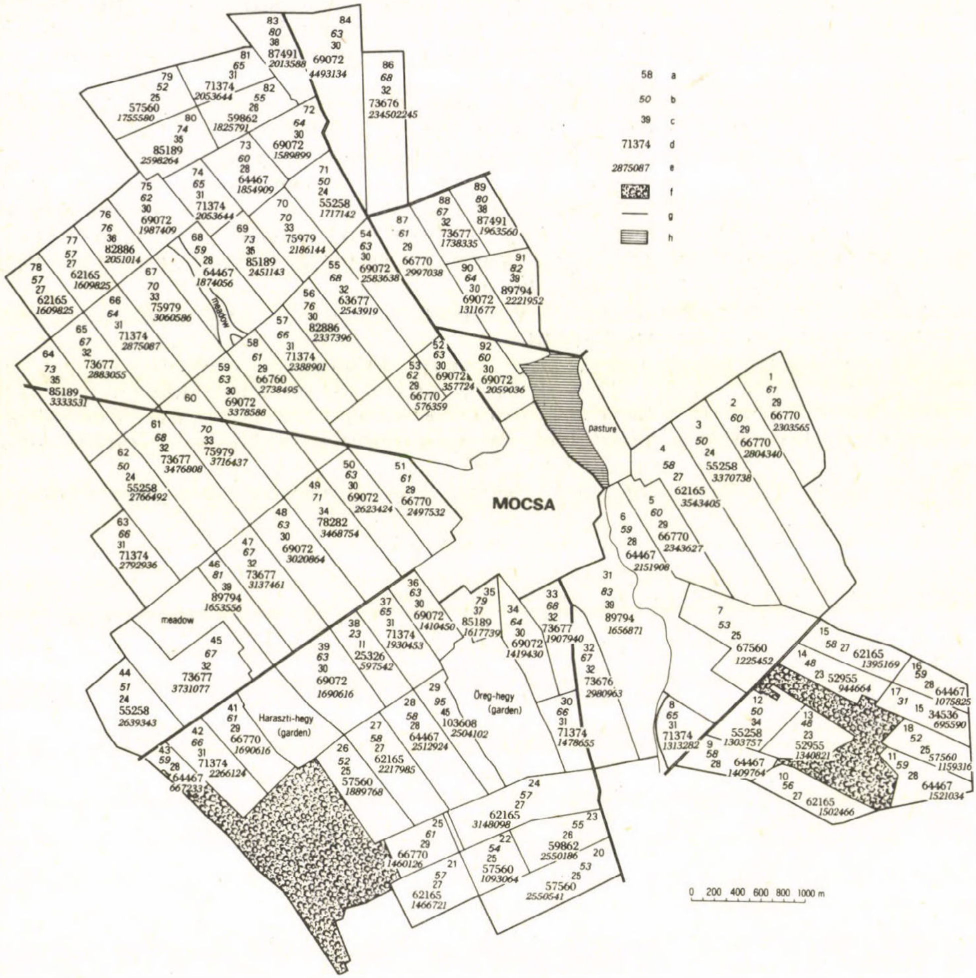

Fig. 1 Land evaluation map for the arable land of the 'Búzakalász' Co-operative Farm, Mocsa (data from GÓCZÁN, L. - MAROSI, S. - SZILÁRD, J. 1969)
a = plot number; b = average numerical value of agricultural habitat; c = coefficient of elasticity in percentage of volume elasticity; d = monetary value of 1 ha land, Ft (1970); e = price of plot, Ft (1970); f = forest; g = boundary of plots; h = lake

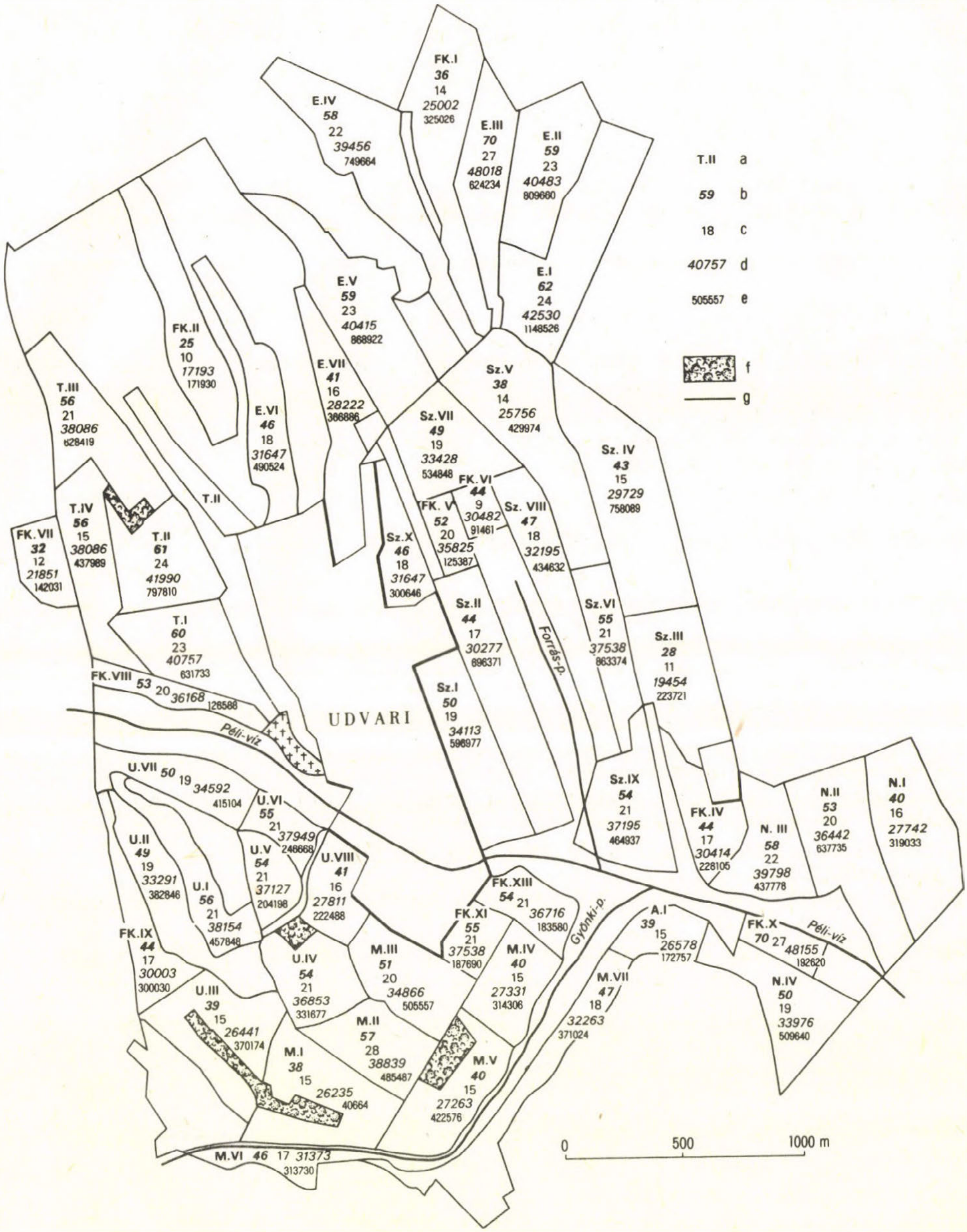

Fig. 2 Land evaluation map for the arable land of the 'Béke' Cooperative Farm, Udvari (data from GÓCZÁN, L. 1974)
For legend see Fig. 1.

The coefficient of elasticity for the agricultural habitats of Mocsa is 0.29, that of Udvari 0.19, i.e. the differences occurring in the quality of agricultural habitats is 29 and 19 per cent, respectively.

The price of land in the two farms is as follows:

$$\text{basic price of land} = \frac{Y}{T} \cdot \alpha \cdot \frac{1}{k},$$

This general formula concretely solved for Mocsa *(Fig. 1)* is total arable land under joint cultivation is 2386 ha (4146 cadastral acres).

The gross production value reached in this area is 27.5 million Ft.*

The gross production value per acre is 11,512 Ft (per cadastral acre: 6,625 Ft).

The correction with the elasticity coefficient of the land:
11,512 . 0.29 = 3338 Ft or
6,625 . 0.29 = 1921 Ft.

The sum above interested by 5 % rate of interest is
3338 . 10 = 66,760 Ft or
1921 . 20 = 38,420 Ft.

$$\text{Basic price of land} = \frac{27,467,310}{2,386} \cdot 0.29 \cdot \frac{1}{0.05} =$$

$$= 66,760 \text{ Ft/ha or}$$

$$\frac{27,467,310}{4,146} \cdot 0.29 \cdot \frac{1}{0.05} = 38,420 \text{ Ft/ca.}$$

In the case of Udvari *(Fig. 2)*:

The area of jointly cultivated arable land is 662 ha (1,150 cadastral acres).

The gross production value reached in the area is:
5,843,990 Ft

The gross production value per hectare is 8827 Ft (per cadastral acre 5082 Ft).

Correction with the coefficient of elasticity for the agricultural habitats is: 8827 . 0.19 = 1677 Ft or
5082 . 0.19 = 966 Ft.

The sum above interested by 5 % rate of interest is
1677 . 20 = 33,540 Ft, resp.
966 . 20 = 19,320 Ft

$$\text{Basic price of land} = \frac{5,843,990}{1150} \cdot 0.19 \cdot \frac{1}{0.05} = 19,320 \text{ Ft/ha.}$$

The comparison of the ecological numerical values of agricultural habitat of their coefficients of elasticity and of the calculated prices of land for the arable lands of the two farms makes it possible to draw interesting conclusions *(Table 5)*.

* For the year 1970, best representing the average conditions of cultivation during the period 1970 - 1980.

Table 5 Comparison of the results of land evaluation for co-operative farms in lowland (Mocsa) and hill (Udvari) areas

	Mocsa	Udvari	Difference per cent
Average numerical value of agricultural habitats on arable land	61	49	20
Average numerical value of agricultural habitats on the plot with the lowest ecological potential	49	25	49
Average numerical value of agricultural habitats on the plot with the highest ecological potential	95	70	26
Elasticity coefficient for agricultural habitats expressed in percentage of volume elasticity	29	19	35
Gross crop production value (Ft per hectare)	11,512	8,827	23
Average price of 1 ha land (Ft)	66,760	33,540	50
One point of agricultural habitat value expressed in money terms (Ft)	1,094	679	38
Price of the plot with the lowest ecological potential (Ft)	54,000	17,000	69
Price of the plot with the highest ecological potential (Ft)	103,930	47,530	54
Average numerical value of soils in the area	63	59	6

The first remark to be made is that the difference between the two farms is not due primarily to soil quality but mostly to variation in relief and water supply. The other conspiciuous difference is shown in the price of land by areal units. In the crop production value the weight of the quality of agricultural habitat is highly different for the two cooperatives, but - viewed in themselves - these only explain the great contrasts in price of land by their percentages.

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